Inclinometer Validation and Analysis of Sedentary Behavior in Older Adolescent University Students

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Abstract

Background

Few objective measurements of sedentary behavior exist. The relationship between sedentary time and body size, as measured by body mass index and waist circumference, has not been well explored in older adolescent university students.

Purpose

The dissertation had two aims. First, validate the inclinometry function of the ActiGraph GT3X+ to measure sedentary behavior in 18 to 20 year-old adolescents. Second, compare sedentary time to body mass index and waist circumference using week-long accelerometry data from older adolescent university students.

Methods

This descriptive study used the ActiGraph GT3X+ device for objective measurement of sedentary behavior. The study used quantitative methods and a convenience sample of 18 to 20 year-old older adolescent university students from a major mid-Atlantic university. Aim 1 was done in a laboratory-controlled environment, testing lying down, sitting, reading a book while seated, playing a video game, watching a video, seated conversation, using a stationary bike, standing, and walking. Aim 2 used week long accelerometry data in free-living conditions. Percent agreement to direct observation determined the accuracy of the inclinometer and multiple regression determined the strength of correlation between sedentary behavior time and body size.

Results & Discussion

For Aim 1, the inclinometer demonstrated poor validity, but the evidence did suggest that using the vector magnitude—a combination of the X, Y, and Z axes—and increasing the accepted threshold of 100 counts per minute to 150 counts per minute may be superior for measuring sedentary and active behaviors. In Aim 2, the sample had high sedentary time and high physical activity time, which is a deviation from the normal population at-large but is consistent with some research in similar age groups. Participants that identified more sedentary extracurricular activities also tended to have higher body sizes. Dissertation results have implications for nurses to address sedentary behavior with patients and health care workers. Nurses should educate and integrate research on sedentary behavior to improve patient outcomes. More research is needed to improve objective measurement of sedentary behavior in older adolescents. Additional analyses could be done using the existing data for future research.

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Chapter 1: Introduction

The dilemma of sedentary behavior (SB) deserves greater attention. Numerous national, international, and interdisciplinary organizations such as the American Academy of Pediatrics (2011), American Heart Association (2011), Institute of Medicine (2011), and the World Health Organization (2010) address the adverse effects of adopting a sedentary lifestyle. Sedentary behaviors, by definition, do not sufficiently raise resting energy expenditure. This can be quantified in terms of metabolic equivalents (METs) of 1.0-1.5 and is generally any behavior done while sitting or lying, but not including sleep (Pate, O'Neill, & Lobelo, 2008).

Youth naturally have the propensity to be active and avoid long stretches of sedentary time (Bailey, Olson, Pepper, Porszasz, Barstow, & Cooper, 1995). However, this tendency is taking a disturbing trend for the worse. Older adolescents experience over 30 hours per week of SB while most do not meet recommended physical activity (PA) guidelines and they significantly increase their weight (Nelson, Story, Larson, Neumark-Sztainer, & Lytle, 2008). Older adolescents in particular have the largest increase in SB and the greatest decrease in PA over the last few decades compared to both younger and older groups (Nelson et al., 2008). Increases in SB have a direct impact on long-term health. For example, SB is implicated in the development of obesity, which has increased nearly 300% in just over one generation (Ogden, Carroll, Kit, & Flegal, 2012).

Sedentary behavior is linked with obesity, and both are associated with numerous co-morbidities, ranging the entire gamut of somatic and psychological disorders (Daniels et al., 2005). Sedentary behavior and weight disturbances are linked with early morbidity and death (AHA, 2011; Barlow & the Expert Committee, 2007; Fontaine et al., 2003). The current generation may even have a shorter life expectancy than their parents (Flegal, Graubard, Williamson, & Gail, 2005; Fontaine et al., 2003). Just as total sedentary time is associated with obesity and metabolic syndrome, individual sedentary episode lengths are independently associated with increased cardiovascular and metabolic risk factors in adults (Healy et al., 2008). This association between sedentary episode lengths and increased risk factors has yet to be adequately explored in youth.

Researchers of SB in older adolescents struggle to find objective measurements of behavior without using the impractical method of continuous direct observation. Accelerometry, however, is one objective method of measuring SB in adults (Nichols, Patterson, & Early, 1992; Plasqui, Bonomi, & Westerterp, 2013), and youth including older adolescents (Carr & Mahar, 2012; Puyau, Adolph, Vohra, & Butte, 2002; Treuth et al., 2004), but a current accelerometer model, the ActiGraph GT3X+ (ActiGraph, LLC, Pensacola, FL), has not had the inclinometry function validated, which may augment the data gathered by the accelerometer (Carr & Mahar, 2012). The inclinometry capability—an innovative feature that determines lying, sitting, and standing positions—may be important in establishing what constitutes a behavior as sedentary (Olds, Maher, Ridley, & Kittel, 2010).

This dissertation also includes an analysis of SB and exploration of the development of an innovative algorithm—the Sedentary Outcome Score (SOS)—to predict health status. The SOS utilizes aspects of sedentary time such as sedentary bout length and breaks in sedentary time. Increased SB time in adolescents has already been positively correlated with BMI and waist circumference (Forshee, Anderson, & Storey, 2004; Klein-Platat et al., 2005; Utter, Neumark-Sztainer, Jeffery, & Story, 2003). The aim of the analysis of SB and SOS is to explore the correlation between sedentary time and validated measures of health, such as BMI and waist circumference. An algorithm combining sedentary bout and break time may improve the strength of the association, as this has yet to be adequately explored and may prove synergistic. The SOS would be valuable given that few objective and subjective measures that are specific to SB exist in the literature (Healy et al., 2008; Klein-Platat et al., 2005) and those that do exist tend to yield a low-to-moderate correlation (Hart, Ainsworth, & Tudor-Locke, 2011).

The theoretical basis for the dissertation is the Theory of Planned Behavior (TPB) as posited by Ajzen (1991). This theory relates behavior choices directly to an individual's intentions, which are influenced by attitudes, subjective norms, and perceived behavioral control. It is an expansion on the Theory of Reasoned Action, which focused on intention as the most important determinant of behavior (Glanz, Rimer, & Viswanath, 2008, p. 70). Attitudes and subjective norms predict intention. The TPB builds on this framework by adding perceived control (a construct similar to self-efficacy) as an antecedent to intentions (Glanz et al., 2008, p. 70). Demographic and environmental factors such as race, gender, and family and friend modeling are external variables embedded in the model, which affect individuals as they follow the TPB pathway to behavior. This theory was shown to explain leisure choices in older adolescents (Ajzen & Driver, 1991) such as sedentary behavior (Rhodes & Dean, 2009). Numerous studies have used the TPB to investigate active behaviors in youth (de Bruijn & van den Putte, 2009; Rhodes & Blanchard, 2008) including in older adolescent college students (Wing Kwan, Bray, & Martin Ginis, 2009).

This research focused on the outcome of the theory—behavior and its measurement. Accurately measuring behavior is essential in the TPB and it consists of four elements: the action, the target at which the action is directed, the context, and the time at which it occurs (Ajzen & Fishbein, 1980). For this dissertation, the behavior measured was the action of SB, in the target of older adolescents, in the context and time of routine daily behavior. Use of the TPB informs the dissertation with respect to explaining and predicting behavior choices at the individual level. The theory explains a modest, but significant, amount of SB choices in older adolescents, typically ranging from r=0.20 to 0.39 (Rhodes & Blanchard, 2008). However, these statistics are based mostly on self-reported questionnaires. If an objective method of measuring SB was reliable and valid, this may improve the explanation of each step in the theory. Alternatively, it may indicate ways in which to adapt the TPB and better explain SB among older adolescents.

Essentially, the TPB assumes that individuals are rational persons who methodically make choices even if it is done more subconsciously rather than overtly (Glanz et al., 2008, p. 76). The theory also assumes that each step occurs in sequence with the major constructs directed towards intentions, which is then the single immediate motivator of behavior (Ajzen, 1991; Glanz et al., 2008, p. 72). Constructs, their relationships, and measurement criteria have been expressly defined, including how to measure behavior, which is based on action, target, context, time (Ajzen, 1991; Glanz et al., 2008, p. 72). This was the most important reason for selecting this theory, in addition to its successful use with SB, PA, and obesity research.

This dissertation was a pilot descriptive study using quantitative methods, objective measures, cross-sectional design, and a convenience sample from a large mid-Atlantic university. The major objective of the dissertation was to improve objective measures of SB in older adolescents and to assess its correlation to health status as measured by BMI and waist circumference. The specific aims were:

1) Validate the inclinometry function to measure SB in 18- to 20-year-old older adolescent university students. Behaviors that were tested were: lying, sitting, reading a book while seated, playing a video game, watching television, seated conversation/talking on phone, using a stationary bike, standing, and walking.
2) Analyze sedentary time compared to BMI and waist circumference using week-long accelerometry data from the older adolescents university students and attempt to develop and test an innovative, valid algorithm (the SOS).

This dissertation is composed of six chapters summarizing the conclusions of the research. The second chapter contains an expanded F31 grant application accepted for pre-doctoral funding through the National Institute of Nursing Research in the National Institutes of Health. Chapter three is a literature review analyzing the current state of research on measuring SB in youth. Chapter four reports the results of the first aim of this dissertation—validation of objective measures of SB in university students including the inclinometer from the ActiGraph GT3X+ device. The fifth chapter contains results of the dissertation's second aim by exploring the sedentary analysis of older adolescent university students and its relationship with BMI and waist circumference. The sixth and last chapter provides a conclusive summary of the completed research.

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Chapter 2: SF 424 Form

PROJECT TITLE

Inclinometer Validation and Analysis of Sedentary Behavior in Older Adolescent University Students

PROJECT SUMMARY/ABSRACT

The American Academy of Pediatrics (2011), American Heart Association (2010), Centers for Disease Control and Prevention (2011), Institute of Medicine (2011), and the World Health Organization (2010) have all recognized the deleterious effects of sedentary behavior (SB) in youth. SB is implicated in the development of obesity and early morbidity and death (AHA, 2010; Barlow & the Expert Committee, 2007; Fontaine et al., 2003). The long-term goal of the program of research is to understand the role of SB in health and wellness in youth while finding interventions for obesity. The major objectives of this dissertation were to find accurate measures of SB in older adolescent university students and find correlations of SB to body size. The proposed pilot study specifically aimed to: 1) validate the inclinometry function to measure SB, and, 2) analyze sedentary time compared to body mass index (BMI) and waist circumference using week-long accelerometry data from older adolescent university students (Forshee et al., 2004; Healy, Dunstan et al., 2008; Klein-Platat et al., 2005; Utter et al., 2003). This descriptive study used objective measures, quantitative methods, and a convenience sample from a large university in the mid-Atlantic region. Participants were 18 to 20 year-old adolescents in the collegiate setting. A goal of 25 participants was used for the first aim, and 75 for the second. Objective measures of body movement and position were done using the ActiGraph GT3X+ (ActiGraph, LLC, Pensacola, FL). Aim 1 was done in

a laboratory-controlled environment, testing lying down, sitting, reading a book while seated, playing a video game, watching television, seated conversation/talking on phone, using a stationary bike, standing, and walking. Aim 2 required participants to wear the GT3X+ device for one week in free-living conditions. Percent agreement was used to determine accuracy of the inclinometer and multiple regression determined the strength of correlation between SB time and body size, controlling for demographics and physical activity.

SPECIFIC AIMS

The American Academy of Pediatrics (AAP) (2011), American Heart Association (AHA) (2010), Centers for Disease Control and Prevention (CDC) (2011), Institute of Medicine (IOM) (2011), and the World Health Organization (WHO) (2010) have all recognized the deleterious effects of sedentary behavior (SB) in youth. “Sedentary” is defined as behaviors that do not sufficiently raise resting energy expenditure, with metabolic equivalents (METs) of 1.0-1.5 and accelerometry values of less than 100 counts per minute (Pate et al., 2008; Troiano et al., 2008). By nature, youth of all ages are active persons that favor short bursts of activity (Bailey et al., 1995). SB is implicated in the development of obesity, which has increased nearly 300% in just over one generation (Ogden et al., 2012). Older adolescents in particular have the largest increase in SB and obesity, and the greatest decrease in physical activity over the last few decades compared to other groups (Nelson et al., 2008). Older adolescent college students experience over 30 hours/week of SB while most do not meet recommended physical activity guidelines and they significantly increase their weight (Nelson et al.). Researchers of SB struggled to find objective measurements of behavior without using the impractical method of continuous direct observation. Additionally, it was unknown whether these objective measures, with or without accelerometry data, strengthened the correlation between SB and health outcomes.

Sedentary behavior is linked with obesity, and both are associated with numerous comorbidities, ranging the entire gamut of somatic and psychological disorders (Daniels et al., 2005). SB and weight disturbances are linked with early morbidity and death (AHA, 2010; Barlow & the Expert Committee, 2007; Fontaine et al., 2003). The current generation may even have a shorter life expectancy than their parents (Flegal et al., 2005; Fontaine et al., 2003). Just as total sedentary time is associated with obesity and metabolic syndrome, individual sedentary episode lengths are independently associated with increased cardiovascular and metabolic risk factors in adults (Healy, Dunstan et al., 2008). This association between sedentary episode lengths and increased risk factors had yet to be adequately explored in older adolescents.

Determining reliable and valid methods of measuring SB was paramount. Accelerometry had already been validated for measuring SB in youth (Carr & Mahar, 2012; Puyau et al., 2002; Treuth et al., 2004). The latest accelerometer, ActiGraph GT3X+, had a feature that had not been validated: an inclinometer. This was an innovative feature that determines lying, sitting, and standing positions, which may be important in establishing what constitutes a behavior as “sedentary” (Olds et al., 2010). If the inclinometer was found to be a poor tool in identifying SB, this dissertation would proceed to use a reliable and valid technique of accelerometry.

The age group of older adolescents was of particular interest because, unlike younger children, they seek identity and values, and are more independent and capable of taking control of their health (Berk, 2007). This study proposed to develop a Sedentary Outcome Score (SOS), which would use an algorithm consisting of combinations of sedentary episodes, breaks in SB and total sedentary time, and link these to validated measures of health such as BMI and waist circumference (Forshee et al., 2004; Healy, Dunstan et al., 2008; Klein-Platat et al., 2005; Utter et al., 2003). Total sedentary time has a low (r=.25-.31), but significant correlation with BMI and waist circumference in youth (Klein-Platat et al.). Recent adult evidence suggests individual sedentary episodes have an even higher correlation (r=.25-.51) (Healy, Dunstan et al.). An algorithm combining SB episode and break length could have improved the strength of the association. This had yet to be explored and would have been valuable given that few measures of SB exist (Healy, Dunstan et al.; Klein-Platat et al.) and those that do exist do not surpass a low-to-moderate correlation (Hart et al., 2011). This novel approach would influence research and practice in this field.

The **broad goal** for this program of research was to enhance understanding of SB in youth. The **major objective** of this study was to improve objective measures of SB in youth and its correlation to health outcomes. The **specific aims** were as follows:

1) Validate the inclinometry function to measure SB in 18 to 20 year-old adolescents. Behaviors to be tested will be: lying down, sitting, standing, reading a book while seated, playing a video game, watching a video, seated conversation/talking on phone, using a stationary bike, and walking.
2) Analyze sedentary time compared to BMI and waist circumference using week-long accelerometry data from older adolescent university students and attempt to develop and test an innovative, valid algorithm (the SOS, using average daily

sedentary episodes and breaks between them and correlate the SOS with participant's BMI and waist circumference).

BACKGROUND AND SIGNIFICANCE

Scope of the Problem

The AAP (2011), AHA (2010), CDC (2011), IOM (2011), and WHO (2010) have all recognized the deleterious effects of SB in youth. Youth do not normally engaged in prolonged bouts of inactivity. Bailey et al. (1995) found that youth spend an average of six seconds in distinct episodes of low and medium level activities. SB is implicated in the development of obesity. Current research notes the national prevalence of youth who are overweight (≥85th percentile) is 33.6% and obese (≥95% percentile) is 18.4% (Ogden et al., 2012). Obesity rates in Virginian adolescents is better than the national average at only 17.2% for overweight and 11.1% for obese (Virginia Department of Health, 2011). Still, obesity increased nearly 300% in approximately one generation (Ogden et al.). Obesity and SB are associated with numerous comorbidities, ranging the entire gamut of somatic and psychological disorders (Daniels et al., 2005) and one study found that 70% of obese youth had at least one risk factor for cardiovascular disease, and nearly 40% had two risk factors (Freedman et al., 2001). Reducing SB to decrease obesity rates by five percent would lower health care costs in the U.S. by $29.8 billion in five years, $158.1 billion in ten years and a staggering $611.7 billion in 20 years (Trust for America's Health, 2012). SB and weight disturbances are linked with early morbidity and death (AHA, 2010; Barlow & the Expert Committee, 2007; Fontaine et al., 2003). Shockingly, some have even speculated that the current generation may have a shorter life expectancy than their parents (AHA; Fontaine et al., 2003). One recent study found that even persons who are normally physically active begin to have impaired glucose management within a matter of days of adopting a sedentary lifestyle (Mikus et al., 2012).

Sedentary behavior research has not gained the level of attention that is focused on physical activity and obesity. However, an increasing number of studies recognize the independent importance of SB on acute and chronic problems in populations such as youth (Freedman et al., 2001; Healy, Wijndaele et al., 2008; Marchand et al., 1997). In fact, some research indicates that efforts to reduce SB may have a greater impact on increasing physical activity than targeting physical activity alone (Epstein et al., 2006; Robinson, 1999). However, measuring, quantifying, and defining SB remains an obstacle (Bennett et al., 2006; Pate et al., 2008). SB is not simply the opposite of physical activity (Olds et al., 2010). For example, it is possible to be both highly physically active, yet still maintain long periods of sedentary time. SB is not simply inactivity. On the contrary, many sedentary choices require interaction of the participants, such as video gaming and seated social conversation.

Older adolescents are of particular concern in this field. First-year college students experience a great amount of independence. For many, this is the first time living away from home. This population is the ideal target population as they are still in older adolescence, falling under Erikson's developmental stage of "identity vs. role confusion" where identifying personal values is a crucial part of development (Berk, 2007). Without the constant influence of parents/guardians, then, this study aims to measure behavior that these youth truly value (in terms of SB and activity). Older adolescents in particular have the largest increase in SB and obesity, and the greatest decrease in physical activity over the last few decades compared to other groups (Nelson et al., 2008). Older adolescent college students experience over 30 hours/week of SB while most do not meet recommended physical activity guidelines and they significantly increase their weight (Nelson et al.). There is a general decline in motivation to increase activity and decrease SB as youth get older. Numerous studies have found that younger adolescents value activity and have a willingness to embrace a healthier lifestyle (Fereday et al., 2009; Jago et al., 2009; Power et al., 2010; Sebire et al., 2011; Simons et al., 2012; Wright et al., 2010). However, motivation decreases with age sometime in the older adolescent years (Bélanger et al., 2011; Lindelof et al., 2012; Moola et al., 2012; Nelson et al., 2009; Njoki et al., 2007). By targeting youth, the greatest potential benefit can be realized by providing a lifetime of positive behaviors that maximizes healthy outcomes.

Objectively Defining Sedentary Behavior

A recent literature review (Chapter 3) found varying subjective and objective measurements of SB that were inconsistent with one another and were modestly correlated with SB. Some studies objectively measured SB and all of these used accelerometers in the research (Blair et al., 2007; Ekelund et al., 2007; Metcalf et al., 2011). Screen time such as using television, computers, and smartphones, are a popular measure of SB, although this was not objectively measured in any study found in the review. One study translated activity questionnaire responses into physical activity scores (Hands et al., 2011), and nine studies used some form of screen time recall/questionnaire response to quantify SB (Bacha et al., 2010; Blair et al.; Cecil-Karb & Grogan-Kaylor, 2009; Hands et al.; Fulton et al., 2009; Nelson et al., 2006; Timperio et al., 2008; Ventura et al., 2006; Westerberg-Jacobson et al., 2010). Subjective measurements were made by parental recall of the youth’s activities, were self-reported by the youth, or were a combination of both. Only two articles combined screen time and an activity component to measure SB (Blair et al.; Hands et al.). Problems with subjective measures stem from recall bias and a desire to please researchers. Correlations and percent agreement tended to be low or even non-significant (Peterson, in revisions). If a standardized, objective method of measuring SB could be developed that combined both movement and behavior (such as accelerometry and inclinometry, respectively) and a risk score developed that correlated to outcomes of SB (such as the SOS), this could lead to fresh solutions and approaches to guide nursing interventions in this field.

The role of daytime sleeping in SB and its measurement is not well researched. Nighttime sleep has distinctive restorative benefits that improve health and is required to maintain optimal body functioning and metabolism (Van Cauter, Spiegel, Tasali, & Leproult, 2008). The relationship between sleep, SB, and exercise is complicated, with evidence suggesting that the timing of each plays a role in health status (Atkinson & Davenne, 2007). Consistent, satisfactory sleep improves metabolic health and is important in hormonal regulation (Morselli, Guyon, & Spiegel, 2012). However, in adults, daytime napping is significantly related to decreased nighttime sleep, increased BMI and waist circumference and higher overall cardiovascular risk (Owens et al., 2010). In the pediatric population, including older adolescents, shorter nighttime sleeping in conjunction with SB is correlated with increased weight (Must & Parisi, 2009).

Although daytime sleep seems to influence health status, research in older adolescents is minimal in terms of relationship with SB and objective measurement. Lack of validated methods of objectively defining and measuring daytime sleeping in older adolescents is one reason for the dearth of information. Accelerometry provides a realistic way to objectively measure SB. This method can also be used to measure sleep, although results can be limited and should include other methods of measurement to improve accuracy (Sadeh, 2011). The design and use of the accelerometers themselves differ in how they are utilized for measuring activity and sleep. Not all accelerometers are validated for measuring sleep (Rosenberger, 2012). Some accelerometers are calibrated for activity, SB and sleep, but placement of the device on the body differs by which measurement is sought (Rosenberger, 2012).

Research Conceptual Model

The Theory of Planned Behavior (TPB) as posited by Ajzen (1991) related behavior choices directly to an individual's intentions, which are influenced by attitudes, subjective norms, and perceived behavioral control. This theory was shown to explain leisure choices in youth (Ajzen & Driver, 1992) such as SB (Rhodes & Dean, 2009). Numerous studies used the TPB to investigate activity behaviors in youth (de Bruijn & van den Putte, 2009; Rhodes & Blanchard, 2008) including adolescent college students (Wing Kwan et al., 2009). The intent of the dissertation was to focus on the distal/outcomes piece of the TPB (see Figure 1). Measuring behavior was essential in the TPB and it consisted of four elements: the action, the target at which the action is directed, the context, and the time at which it occurs (Ajzen & Fishbein, 1980). The behavior that was measured was the action of SB, in the target of youth, in the context and time of daily living. Use of the TPB informs this program of research, which aims to explain and predict behavior choices at the individual level. TPB explains a modest, but significant, amount of SB choices in older adolescents, typically ranging from r=0.20 to 0.39 (Rhodes & Blanchard, 2008). However, these statistics were based mostly on self-reported questionnaires. If an objective method of measuring SB was reliable and valid, this would improve the explanation of each step in the TPB, or may indicate ways in which to adapt the TPB so as to better explain SB among youth. Although the study did not integrate the TPB as whole—instead focusing solely on outcomes—the TPB was the foundation for future research and is essential in guiding each phase, including the dissertation. Once reliable and valid methods of measuring SB were established, future theory-based research can focus on other aspects of the theory including intentions, attitudes and self-efficacy. Interventions to reduce SB will be built upon these principles.

Impact of Study

Accelerometry was validated for measuring SB in adults (Reilly et al., 2003), and youth (Carr & Mahar, 2012; Puyau et al., 2002; Treuth et al., 2004), but the current accelerometer model, the ActiGraph GT3X, had not had the inclinometry function validated which could have augmented the data gathered by the accelerometer (Carr & Mahar). The inclinometry capability—an innovative feature that determines lying, sitting, and standing positions—could have been important in establishing what constituted a behavior as "sedentary" (Olds et al., 2010). Perhaps even more novel was the proposed development of an algorithm—the SOS—to predict health measures that utilize two aspects of sedentary time: sedentary bout length and breaks in sedentary time. Increased SB time in youth had already been positively correlated with BMI and waist circumference (Forshee et al., 2004; Klein-Platat et al., 2005; Utter et al., 2003). The aim of the SOS was to improve the correlation between sedentary time and validated measures of health, such as BMI and waist circumference. Total sedentary time had a low (r=.25-.31), but significant correlation with BMI and waist circumference in youth

(Klein-Platat et al., 2005). Recent adult evidence suggested individual sedentary bouts had an even higher correlation (r=.25-.51) (Healy, Dunstan et al., 2008). An algorithm combining sedentary bout and break time could have improved the strength of the association as this had yet to be explored and could have been synergistic. The SOS would have been valuable given that few objective and subjective measures that were specific to SB existed in the literature (Healy, Dunstan et al., 2008; Klein-Platat et al., 2005) and those that did exist tended to not surpass a low-to-moderate correlation (Hart et al., 2011).

Results of the study had the potential to advance how SB was understood and measured in youth, impacting future interventions in this emerging field. Establishing reliable and valid measures of SB in youth would enable future theory-based research to design targeted interventions using antecedent components, i.e., subjective attitudes, social norms, and perceived control, and mediator components of the TPB (Ajzen, 1991) to improve health and prevent disease. This pilot study was the foundation for additional innovation in understanding, measuring, and combating SB in youth.

RESEARCH STRATEGY/METHODS

Design/Setting

The proposed research was a pilot study with two main objectives: 1) validate the inclinometry function of the ActiGraph GT3X to measure SB in 18 to 20 year-old adolescents; and 2) analyze sedentary time from week-long accelerometry data and attempt to develop an innovative algorithm, the SOS, that uses the longest average daily sedentary episode and average total daily sedentary time and correlates the SOS with the participant's BMI and waist circumference. Although it was hoped that the inclinometry feature would be successfully validated (Carr & Mahar, 2012), the carrying out of the study did not predicate on its success since the ActiGraph GT3X+ accelerometry function had already been validated for measuring SB in adolescents (Carr & Mahar; Treuth et al., 2004). The conceptual model guiding this study is shown in Figure 1. Specifically, the **first aim (inclinometer validation)** was to investigate the precision and accuracy of the inclinometer to measure SB, and the overall ability of combining both measures to detect SB in older adolescent university students in the setting of laboratory-controlled conditions. The **second aim (analysis of SB and algorithm development)**—the SOS—was attempted to be done by the PI with the aid of Dr. Rovnyak, the statistician and mathematician consultant, using the 1-week accelerometry data from the participants in free-living conditions.

The **first aim** and phase was to determine the validity and reliability of the inclinometer feature on the ActiGraph GT3X to measure SB in older adolescent college students. Behaviors tested were: lying down, sitting, reading a book while seated, playing a video game, watching television, seated conversation/talking on phone, using a stationary bike, standing, and walking (all for 5 minutes). This type of protocol has been successfully used in accelerometer validation including the ActiGraph GT3X+ (Carr & Mahar, 2012; Puyau et al., 2002; Treuth et al., 2004). Somewhat important to this protocol was the use of a stationary bike, which was known to be accurately detected by accelerometry as activity (not sedentary), but it was unknown if the fact that the participant was seated would affect the ability of the inclinometer to accurately detect that the behavior was not sedentary. Acquired accelerometry and inclinometry data were compared to direct observations by the PI. Validity of the inclinometer was done by comparing the inclinometer output (lying, sitting, standing) with the criterion of direct observation of SB (lying down, sitting, reading a book while seated, playing a video game, watching television, seated conversation/talking on phone). This method was previously established as valid (Sirard et al., 2005). The PI compared results of the inclinometry data to the accelerometry data to determine if there was a match between SB as measured by accelerometry and by inclinometry (Carr & Mahar).

During the data collection phase for the **second aim**, older adolescent (18 to 20 year-old) college students wore the accelerometer for 7 days. For the device data to be considered sufficient to be included for analysis, participants needed to accumulate at least 10 hours of wear time per day, with a 4-day minimum during the week of collection (minimum 40 total hours). The ActiGraph GT3X+ software was able to distinguish time point data from the accelerometers from as little as one second. The PI programed the software to determine total sedentary time and record sedentary episode lengths using the established accelerometer criteria of ≤100 counts per minute (Treuth et al., 2004). Entering these parameters, the software returned the daily sedentary episode lengths as well as daily total sedentary time. Then, in collaboration with the statistician consultant Dr. Rovnyak, the PI attempted to develop the SOS using these variables to find the algorithm that best linked the parameters with BMI and waist circumference. Given the skewed data, pursuing the SOS was not reasonable, and an analysis of the sedentary time in correlation with BMI and waist circumference was completed instead.

<u>Subjects and settings</u>

The target population included older adolescents of varying socio-demographic backgrounds. Study subjects were a convenience sample of 18 to 20 year-old college students enrolled at the University of Virginia. Recruitment was done through several methods. It was expected that 25 participants would be enrolled for **aim one** and 75 participants for **aim two** (see “Power Analysis” section below). Participant completion and usable device data exceeded 90% in most studies for youth (Blair et al., 2007; Carr & Mahar, 2012; Hänggi, Phillips, & Rowlands, 2013; Metcalf et al., 2011; Steele, van Sluijs, Cassidy, Griffin, & Ekelund, 2009). Missing data had been noted to range from 0% to 3% (De Vries, Bakker, Hopman-Rock, Hirasing, & Van Mechelen, 2006). All departments that consented to help emailed 18 and 20 year-old students about the study. Undergraduate enrollment was over 14,600, so nearly half that amount were in the 18 to 20 year-old range. The sample was augmented through use of flyers, advertisements, and referrals. Gift cards were given to each participant at the successful completion of the study. Inclusion criteria: adolescent males and females aged 18 to 20 years-old able to: (1) wear an accelerometer, (2) perform the following activities: lie down, sit, read a book while seated, play a video game, watch television, engage in seated conversation/talk on phone, pedal on a stationary bike, standing, and walk unassisted. Exclusion criteria: (1) those unable to perform the above activities, (2) non-English speakers, (3) those with any type of lower body injury or condition such that performing the above activities was difficult, worsened the condition, or sufficiently altered the participant’s daily routine so as to change the normal living habits as judged by the participant and PI. For example, potential participants who were otherwise healthy, but used crutches, were not eligible.

The **first aim** of the study was conducted at a private location at the Youth-Nex Center facilities, which had resources available for use by the PI to do direct observation of participants while they performed the various activities wearing the ActiGraph

GT3X+. The **second aim** of the study was also at the Youth-Nex Center facilities for meeting with participants: obtaining sample demographics; measuring height, weight, and waist circumference; and setting-up the accelerometers for subject use. Participants returned exactly one week later to return the devices and the PI verified the data collected by the ActiGraph GT3X+. Algorithm development utilized School of Nursing computers in dedicated areas for doctoral nursing students, which had statistical software packages (SPSS 19).

Power Analysis

Power analysis was done for each phase of the study with the aid of Dr. Sirard and Dr. Rovnyak and the computer program nQuery. Because this was a pilot study, it was expected that the study could have been underpowered, but every effort was made to meet the power criteria. Sample size estimates were based on number of participants used in similar research and following general statistical consensus guidelines. Based on general principles of statistics (Harrell, 2001) the **first aim** of the study, validating the inclinometer, needed approximately 20 participants. The **second aim** required around 60 participants. These numbers were comparable to studies with similar objectives (Carr & Mahar, 2012; Puyau et al., 2002; Treuth et al., 2004) and lie within the guideline of 10-20 participants per variable (Harrell, 2001). Estimates using the program nQuery for multiple regressions had similar results. For the **first aim**, the effect size was estimated at 0.5, power of 0.8, alpha of 0.05, with 1-2 predictors, which would require 18-23 subjects (Cohen, 1992). The **second aim** effect size was estimated at 0.25, power 0.8, alpha 0.05, with 3-4 predictors. Sample size for this aim required between 59 and 65 participants (Cohen, 1992). To meet these requirements, the goal of the proposed study was to enroll

25 participants for the first aim, and 75 for the second. This allowed for an attrition rate and/or rejection for missing or non-useable data of 20%. Power analysis was especially difficult for the **second aim** because the components to the SOS algorithm had not yet been determined until the data had been gathered, yet it has been decided that no more than 4 variables would be entered when doing the multiple regression to calculate correlations. Although every effort was made to fully power this dissertation, the pilot study served as a foundation for larger, more comprehensive future studies.

Accelerometers were an objective tool for collecting activity data. Accelerometers had been used to objectively measure activity since the 1990s and support for their validation was growing (De Vries et al., 2006; Hänggi et al., 2013; Kaminsky & Ozemek, 2012; Santos-Lozano et al., 2012; Yang & Hsu, 2010). Precisely and accurately capturing movement and SB was critical in determining how these bouts, and breaks between them, were related to biophysical characteristics such as waist circumference and BMI (Carr & Mahar, 2012).

Instruments

Completing the personal characteristic information took approximately 5 minutes for each participant. For aim 1, the laboratory testing of the accelerometer took an additional 60 minutes to complete. For aim 2, the participant wore the accelerometer for 7 days. Participants needed at least 4 days of data, with at least 10 hours per day and one weekend day, to have been considered usable.

1. Personal Information Form (PIF). A one-page, 10-item form, developed by the PI was completed for each participant (see Appendix A). Items 1 through 4 were simple demographic attributes completed by the participant: gender, age, year in school, ethnicity. Item 5 was free listing of extra curricular activities. Items 6 through 9 were body measurements taken by the PI for each participant (waist circumference, height, weight, BMI). BMI was calculated using the Center for Disease Control and Prevention's (CDC) standardized BMI calculator using the participant's height and weight measures (CDC, 2013). Nominal data was treated as interval by dummy coding. Completion time was 5 minutes for the participant, and 5 minutes for the PI, or 10 minutes total.

2. ActiGraph GT3X+. The ActiGraph GT3X+ device was used to assess activity (ActiGraph, LLC, Pensacola, FL). Its purpose was to objectively measure activity, specifically in terms of body movement and position (ActiGraph, 2013). Empirical, objective measurement of movement was the conceptual basis for the accelerometer. Movement was captured in 3 axes and expressed at a rate of counts per minute (cpm). Position was recorded using the angle of the device with one of four values: off, lying, sitting, standing. Data was collected at 30 Hz and then aggregated during the post-collection processing stage to 10-second intervals. Times of >60 minutes of accelerometer cpm values = 0 or inclinometer = off were considered times when the device was not worn (Troiano et al., 2008). After removal of these data points, days with at least 10 hours of valid accelerometer data were used for further processing (Matthews et al., 2008). Count values obtained from the GT3X+ were categorized by intensity level by applying the accelerometry cutpoints used for the 2003-2004 NHANES data (sedentary < 100 cpm; light, 101-2019 cpm; moderate, 2020-5998 cpm; vigorous, >5999 cpm) (Carr & Mahar, 2012; Troiano et al., 2008). Although cutpoints helped organize data based on level of activity, data was stored as continuous rather than categorical. The inclinometer was categorical. The GT3X+ was a small monitor that housed both an accelerometer and inclinometer, weighing only 19 grams (ActiGraph, 2013). Participant completion and usable device data exceeded 90% in most studies for youth (Blair et al., 2007; Carr & Mahar, 2012; Hänggi et al., 2013; Metcalf et al., 2011; Steele et al., 2009). Missing data was noted to range from 0% to 3% (De Vries et al., 2006). Accelerometry precision ranged 80-98% for sedentary activity in laboratory conditions (Carr & Mahar, 2012; Sasaki, John, & Freedson, 2011) and in free-living conditions (Kaminsky & Ozemek, 2012; Santos-Lozano et al., 2012). Intra-class coefficients ranged 0.31-0.998 and coefficients of variation (CV) ranged 1-22% (De Vries et al., 2006; Santos-Lozano et al., 2012). Precision of the inclinometry feature of the GT3X+ had not been reported.

The GT3X+ accelerometer construct validity was high, typically ranging r=0.39-0.90 (De Vries et al., 2006) or, specifically to SB, between 80-98% agreement to direct observation (Carr & Mahar, 2012; Hänggi et al., 2013). Only one study had investigated the construct validity of the GT3X+ inclinometer, which found 63-67% agreement to direct observation (Carr & Mahar, 2012). Criterion validity was supported by several studies in comparison to the older accelerometer model (De Vries et al., 2006; Kaminsky & Ozemek, 2012; Sasaki et al., 2011). Accuracy of the inclinometer was tested in aim 1 of the study. With the exception of a single study which had one participant (but several accelerometers simultaneously) (Santos-Lozano et al., 2012), other studies had 34-50 subjects ranging in age from childhood (Santos-Lozano et al., 2012) to older adolescent and adulthood (Carr & Mahar, 2012; Hänggi et al., 2013; Kaminsky & Ozemek, 2012; Sasaki et al., 2011).

The ActiGraph GT3X+ accelerometer/inclinometer device was an optimal instrument for the study. Feasibility of using the GT3X+ appeared highly favorable given the high rate (>90%) of participant completion with usable data (Blair et al., 2007; Hänggi et al., 2013; Metcalf et al., 2011; Steele et al., 2009), and was successfully used within the population of older adolescent college students (Carr & Mahar, 2012). The GT3X+ was small, unobtrusive, and essentially tamper resistant device which was well-tolerated by youth and did not hinder activity (ActiGraph, 2013; de Vries et al., 2006). The purpose of aim 1 was to test the precision and accuracy of the GT3X+ inclinometer with sedentary behavior. The accelerometry feature of the GT3X+ was highly precise with sedentary behaviors in both laboratory (Carr & Mahar, 2012; Sasaki et al., 2011) and in free-living conditions (Kaminsky & Ozemek, 2012; Santos-Lozano et al., 2012) according to accepted standards (Landis & Koch, 1977). Support for the validity of the accelerometer in measuring sedentary behavior was seen by high accuracy in comparison to direct observation with 80% or more congruency (Carr & Mahar, 2012; Hänggi et al., 2013). Additionally, the ActiGraph had the highest accuracy in comparison to other accelerometer devices (De Vries et al., 2006).

The inclinometer was a new technology device that appeared to have support for validation (Carr & Mahar, 2012) but nonetheless tested inferior to accelerometry in the laboratory setting compared to the criterion measure of direct observation for sedentary behavior. This, however, did not mean that it lacked positive utility in calculating the SOS algorithm as part of aim 2. However, given the skewed data for aim 2, the SOS was not pursued. Widely accepted norms, which tested for minimally important differences, for defining activity level used the accelerometry cutpoints used for the 2003-2004

NHANES data (sedentary < 100 counts/min; light, 101-2019 counts/min; moderate, 2020-5998 counts/min; vigorous, >5999 counts/min) (Carr & Mahar, 2012; Troiano et al., 2008). Time spent coded as lying and sitting was accepted as sedentary behavior with the inclinometer (Carr & Mahar, 2012; Olds, Maher, Ridley, & Kittel, 2010).

Procedures

The study was submitted for review to the University's Institutional Review Board (IRB). Informed consent was obtained from the participants. Subjects were assigned a random identification number for use on all completed forms and when distributing the accelerometers for use. For **aim 1**, participants were asked to: (1) complete the PIF (see Appendix A), (2) have the PI measure waist circumference, height, and weight, and (3) complete the following activities in the laboratory-controlled setting: lying down, sitting, reading a book while seated, playing a video game, watching television, seated conversation/talking on phone. For **aim 2**, participants were asked to: (1) complete the PIF (see Appendix A), (2) have the PI measure waist circumference, height, and weight, and (3) wear the GT3X+ device and return it at the completion of one week. The PI determined the support for accuracy of the inclinometer after **aim 1** and then worked on analyzing SB and attempting to pursue the algorithm development in **aim 2**.

Data Analysis

Data analysis of **aim 1** required determining the accuracy and precision of the GT3X+ device in measuring common SBs based on inclinometry. Sitting positions were considered sedentary. Established accelerometry cutoff values of less than 100 cpm were considered sedentary (Treuth et al., 2004). Accuracy was calculated as percent agreement, in minutes, between the criterion measure of observed anatomical position and the inclinometer recorded position. The 95% confidence interval was calculated for the mean correctly coded for body position. Significance was determined based on whether the 95% confidence interval spans the criterion of 60 minutes (length of each **aim 1** session) correctly. Data analysis of **aim 2** involved only the ActiGraph data gathered during the week-long wear time by participants. The device software calculated total sedentary time. Multiple regression analyses were done to find correlations between participant BMI, waist circumference while controlling for demographics and physical activity. While the algorithm for the SOS could not be developed, several methods of developing the algorithm had already been discussed with the PI and the statistician consultant. Validity of the SOS would have been based on finding statistical significance with a two-tailed alpha of 0.05 based on the models described below. Two-tailed significance was required since it was unknown what directional impact the following models would have on waist circumference and BMI. The following methods were attempted in constructing the SOS, with more to be tried once data had been obtained:

(a) used just longest sedentary episode length or total sedentary time;

(b) used ratios of total sedentary time and longest sedentary episode;

(c) used quadratic terms: include the squares of the two predictors, in addition to the linear terms.

(d) used one predictor: the geometric mean of the longest sedentary episode length and total sedentary time. The geometric mean was simply the square root of the product of those two numbers. One use of it was to average quantities that are on different scales. In this case, the total sedentary time longer than the longest sedentary episode length, so they would tend to have somewhat different ranges. It had the property that an increase by some proportion, such as 10%, in one of the variables, has the same effect on the geometric mean as an increase by the same proportion of the other variable. That was not true of the arithmetic mean (Sheskin, 2004).

(e) the product of longest sedentary episode length and total sedentary time. This was the square of the geometric mean.

(f) did regressions such as in (a) and (b) and looked at the estimated coefficients for the two predictors. Then define a single variable that was the same linear combination as the model produced (or was a multiple of it).

Potential limitations

Potential limitations limited both aims. First, the ActiGraph GT3X+ inclinometry feature failed to be a precise and accurate measure of SB. Originally, the PI believed that the inclinometer would be successfully validated (Carr & Mahar, 2012), the dissertation was able to continue with **aim 2**, as accelerometry had been validated previously to measure SB (Puyau et al., 2002; Reilly et al., 2003, Treuth et al., 2004). Second, inadequate wear-time by the participants resulted in some insufficient data being collected in **aim 2**. This limitation was reduced through continued enrollment in the study until at least 60, with a goal of 75, valid results were collected. Third, small variability in participant BMI and waist circumference made calculating correlations between these measures and sedentary time somewhat difficult. Because the study was a pilot, finding a trend was considered adequate rather than necessitating statistical significance. Fourth, some minorities were under-represented in the dissertation. The PI attempted to over-recruit minorities in an effort to have adequate inclusion in the study. As recruitment took place, participants were screened for ethnicity and higher BMI to give variety to the sample. For example, when the recruitment sample already had 30 Caucasian participants, no additional Caucasians were accepted until minorities had been recruited in an attempt to match the university's demographics.

Preliminary studies

Preliminary course work in pediatric exercise physiology taught by the co-sponsor Dr. Sirard, review of sedentary literature, and expert opinion all agreed that accelerometry was able to measure SB in older adolescents. More importantly, Dr. Sirard and the PI finished gathering accelerometry and inclinometry data on school children and preliminary results appeared promising in being able to develop the SOS. Recent evidence suggested that SB was a sitting-position phenomenon (Pate et al., 2008). Sedentary came from Latin "sedere" meaning "to sit" (Olds et al., 2010). Inclinometry was a new technology that had yet to be sufficiently validated (Carr & Mahar, 2012), but had great potential in being able to measure SB, based on the notion of a participant's position (lying, sitting, or standing). Additionally, a recent study in an adult population found that breaks in sedentary time were associated with waist circumference (Healy, Dunstan et al., 2008). Essentially, this preliminary study indicated that reducing the longest daily sedentary episode would benefit waist size, and by extension, overall health. Therefore, this study aimed to look for a link between sedentary time and health measures of BMI and waist measurements. The result of this study gave preliminary data for future research to explore this area.

Timeline

Projected total time: 17 months

Months 1 – 3 (3 months): Design/Planning phase: IRB approval, preparation of materials and software, orientation for the research study. Months 4 – 11 (8 months): Empirical phase: Participants recruited for each aim (first aim [device validation] = 3 months, second aim [device data collection] = 4 months), data collection. Also, data analysis for first aim was done before proceeding to second aim. Months 11 – 13 (3 months): Analytical phase: Data analysis for second aim, with some overlap with completion of aim 2. Months 7 – 17 (11 months): Dissemination phase: completion of writing phase, preparation of results for journal submission for both aim one and aim two results.

Estimated budget

The estimated budget for this proposal was fairly minimal. Six new GT3X+ devices ($300 each) would supplement the amount of devices available to the PI through the Youth-Nex Center at the Curry School of Education. The ActiLife program for using the GT3X+ cost $200 for one license to be used on PI-provided computer. Incentives were $20 gift cards for participants, with the budget assuming 25 and 75 participants for each aim respectively (total $2000). Only $50 was anticipated for supplies. Total anticipated direct costs were $4050.

PROTECTION OF HUMAN SUBJECTS

This study included human subjects and was subject to the IRB of the University of Virginia for review once the PI's committee had approved the research proposal.

Risks to Human Subjects

a. Human subjects involvement and characteristics, and design

Older adolescent men and women (18 to 20 years-old) who were college students at the University of Virginia were invited to participate in the study and sign an informed consent form. The study was completed in two phases: 1) validation of inclinometer to measure common sedentary activities; and 2) data accumulation through participants wearing accelerometers for one week. After completing informed consent forms, participants completed a confidential participant demographic form, the information for which was used to calibrate the accelerometers. Inclusion criteria were: older adolescent males and females aged 18 to 20 years-old able to wear an accelerometer and perform the following activities: lie down, sit, read a book while seated, play a video game, watch television, engage in seated conversation/talk on phone, ride a stationary bike, stand, and walk.

Rationale for inclusion criteria were to:

- include youth of the older adolescent age (18-20) who were able to give informed consent (without the need for parental permission);
- participants must have been able to perform regular daily activities including SB in order for the accelerometer to be validated and used for data collection.

Exclusion criteria were: those unable to perform the above activities; non-English speakers; pregnancy; and those with any type of lower body injury or condition such that performing the above activities was difficult, worsened the condition, or sufficiently altered the participant's daily routine so as to change the normal living habits as judged by the participant and PI. For example, potential participants who were otherwise healthy, but used crutches, were not eligible. Obesity was not a criterion for exclusion for the study unless the participant cannot perform the above daily activities.

b. Sources of Materials

Sources of materials included simple demographic information, namely: age, sex, height, weight, and waist circumference. Other sources included accelerometry and inclinometry data calibrated to the demographical information. Personal contact information was collected from the participants to facilitate device return. Personal information and device data were kept separate, both under a two-lock system located at the School of Nursing.

c. Potential Risk

Although all participants were at least 18 years of age, older adolescent university students, most typically living away from home for the first time, women, and minorities could arguably have been considered as potential vulnerable populations. During the consent process, participants were told that they could withdraw from the study at anytime. The ActiGraph GT3X+ was a very small device that was worn using an adjustable and stretchy band around the waist, which could potentially have been seen as uncomfortable or unattractive. The participant was informed that he or she may stop participating at any time.

Adequacy of Protection against risk

Informed consent: After receiving IRB approval, recruitment began using IRB-approved emails, flyers, and advertisements. The recruitment emails were administered by university departments that consented to email their students. Flyers and advertisements were placed on community boards in university buildings and around local university centers, fraternities and sororities. Referrals from participants were also an acceptable recruitment method. Coercion was not used and any person helping with recruitment was not offered any incentive for recruiting participants. The applicant arranged for individual date and times that were mutually acceptable. Participant incentives were in the form of gift cards upon completion of the study. Gift cards were in the amount of $20 to Amazon.com. The applicant was in compliance with all NIH and University of Virginia IRB requirements throughout the entire process. All participants were notified that they could voluntarily withdraw from the study at any time without penalty and all materials related to their participation could be destroyed at their request. No children/adolescents under the age of 18 were included in the study.

Protection Against Risk: Procedures for protecting against or minimizing potential risks included using confidential participant identification numbers and separating personal contact information from collected device data. Participants who experienced any excessive discomfort from wearing the ActiGraph GT3X+ or had distress from participating in the validation activities were allowed to stop at any time. Any adverse effects would have been reported to the IRB immediately, had there been any.

Potential Benefit to Subjects and Others

Participants may have decided to make lifestyle changes knowing that they were participating in a study that was investigating SB and activity patterns. Participants may also have benefitted from getting feedback on their physical activity. The minimal risks to subjects were counterbalanced by the knowledge that they were contributing to the body of knowledge regarding validation of the ActiGraph GT3X+ and potentially new methods of measuring SB. Participants had the choice to withdraw from the study at anytime.

Importance of Knowledge to be Gained

Research findings could have potentially validated the inclinometer of the ActiGraph GT3X+ as a valid and reliable method for measuring SB. A significance (p<0.05) between sedentary episode length, total sedentary time and health measures (BMI and waist circumference) could have been found had the data not been skewed. The SOS could have provided a novel method for understanding the importance of both sedentary episode lengths and total sedentary time on health had the data not been skewed.

Inclusion of women and minorities

Inclusion of Women: This study included both women and men. University of Virginia was approximately 55% female, and 45% male.

Inclusion of Minorities: This study included minorities. Ethnic minority students at the University of Virginia numbered approximately 28%.

The applicant attempted to over-recruit minorities in an effort to have adequate inclusion in the study.

INCLUSION OF CHILDREN

The study used the definition of youth to describe the participants, who are 18 and 20 year-old males and females, which fit NIH's definition of children. The age range was selected based on the fact that this group was more likely than younger children to have control over decisions of health, such as sedentary choices. Additionally, this group was more accessible to recruitment through the available means at the University of Virginia. The PI had experience working, teaching, and interacting with this age group. Furthermore, both the PI's sponsor (Dr. Kulbok) and co-sponsor (Dr. Sirard) were experts in working with youth.

Targeted/Planned Enrollment Table

This report format should NOT be used for data collection from study participants.

Study Title: Inclinometer Validation and Analysis of Sedentary Behavior in Older Adolescent University Students

Total Planned 100

TARGETED/PLANNED ENROLLMENT: Number of Subjects			
Ethnic Category	**Sex/Gender**		
	Females	**Males**	**Total**
Hispanic or Latino	*5*	*5*	*10*
Not Hispanic or Latino	*50*	*40*	*90*
Ethnic Category: Total of All Subjects *	55	45	*100*
Racial Categories			
American Indian/Alaska Native			
Asian	12	10	22
Native Hawaiian or Other Pacific Islander			
Black or African American	13	12	25
White	30	23	53
Racial Categories: Total of All Subjects *	55	45	100

* The "Ethnic Category: Total of All Subjects" must be equal to the "Racial Categories: Total of All Subjects."

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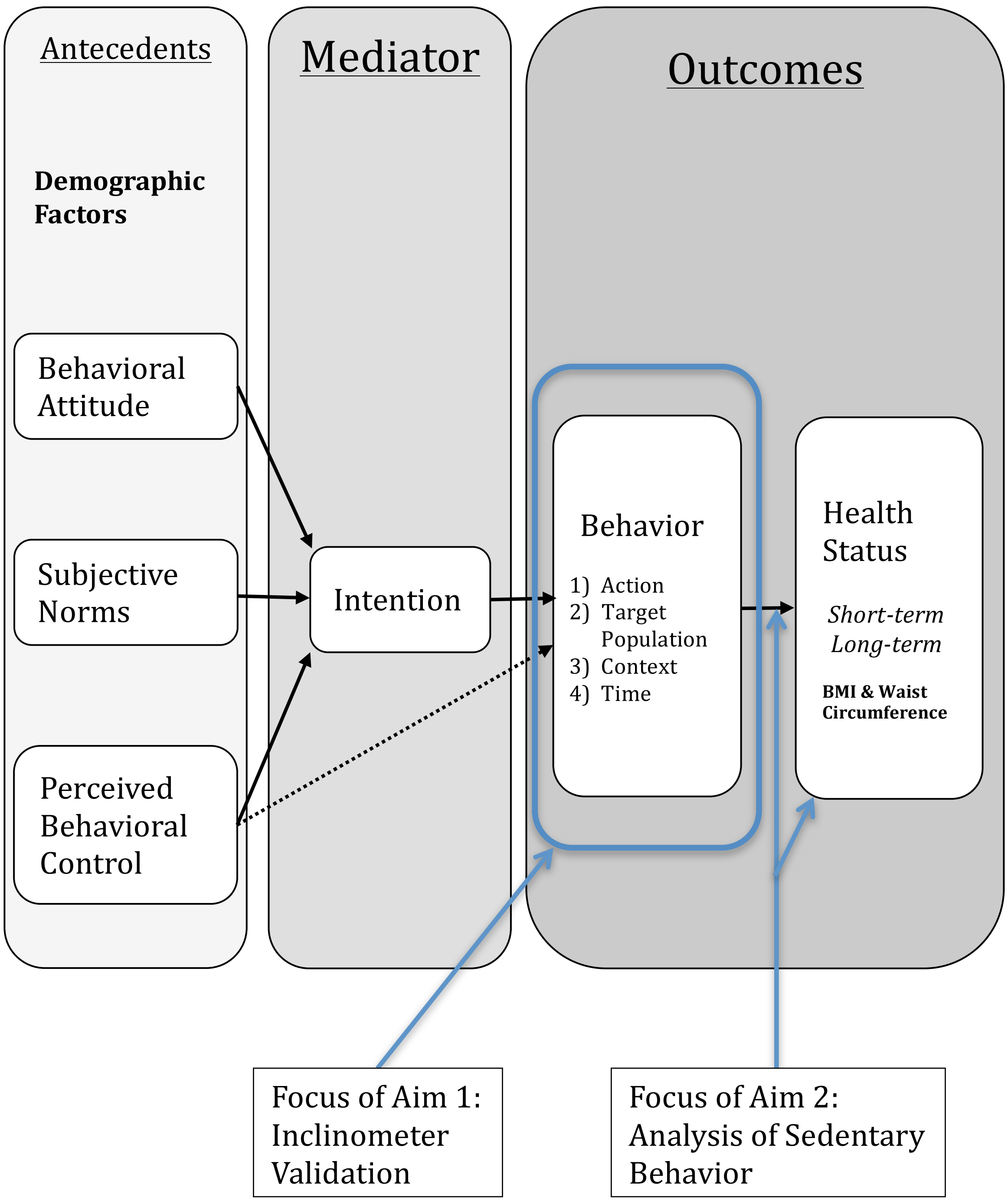
Figure 1. Dissertation Theoretical Framework of Sedentary Behavior as Adapted from the Theory of Planned Behavior



Adapted from Theory of Planned Behavior, Ajzen, I. (1991). The theory of planned behavior. Organizational behavior and human decision processes, 50(2), 179–211. doi:10.1016/0749-5978(91)90020-T

Appendix A

ID #: ____________

Date: ____________

Daily Activity in College Students Study

Principal Investigator: Neil Peterson, MSN, RN, FNP-C
Administrative Site: University of Virginia
Department: School of Nursing
Address: Charlottesville, VA 22908

Personal Information Form (PIF)

Instructions: Please provide some background information about yourself by **checking** (√) your response or filling in the blanks. If you do not care to answer a question, leave it blank.

---

1. What is your sex / gender? (0) Male ____ (1) Female ____

2. What is your age in years? __________

3. How many semesters of school have you completed? __________

4. What is your primary race / ethnicity?

   (0) Caucasian / White ____ (1) African American / Black ____ (2) Asian ____

   (3) Hispanic ____ (4) Other (please describe) ____________________________

5. What are your extracurricular activities? (ex: running, weight-lifting, video gaming, reading, etc.)

____

____

____

THANK YOU!

To be completed by staff:

6. WC: __________ 7. Ht: __________ 8. Wt: __________ 9. BMI: __________

Chapter 3: Manuscript 1 – Defining Sedentary Behavior:

A Review of Pediatric Studies

Target journal for submission: Pediatric Nursing

Defining Sedentary Behavior: A Review of Pediatric Studies

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Abstract

Sedentary behavior (SB) is increasing among children. SB can lead to acute and chronic conditions and even a decrease in life expectancy. Defining SB in a standard way guides research and practice. This literature review describes the theoretical and operational definitions of SB used in recent longitudinal studies that addressed the pediatric obesity epidemic. Using three electronic databases, PubMed, Google Scholar, and CINAHL, 13 articles from January 2006 to December 2011 were collected based on the search terms pediatric, childhood, obesity, overweight, sedentary, inactive, inactivity and longitudinal. Articles were organized by study purpose, study length, sample size, age of subjects, measurement of obesity, theoretical and operational definitions of SB, rationale for definitions, and subjective or objective measurement of sedentary behavior. The review revealed inconsistencies in defining and measuring SB, an absence of theoretical foundations for a definition, and a lack of integration of physiological concepts. The two main definitions of SB were (a) low counts/min by accelerometry; and (b) screen time. Further research is needed to determine what constitutes SB, ways to measure SB, and the dose-wise effect of SB on childhood weight and health.

Key words: sedentary behavior, obesity, childhood, inactivity

Defining Sedentary Behavior: A Review of Pediatric Studies

Children, by nature, are persons who favor short bursts of activity. For example, Bailey et al. (1995) found that six- to ten-year-old children spent an average of 6 seconds in multiple distinct episodes of low and medium level activities throughout the day. Sedentary behavior (SB) is thus a contradiction of normal childhood development and activity. Furthermore, SB is implicated in the development of pediatric obesity. Current research (Ogden, Carroll, Curtin, Lamb, & Flegal, 2010) suggests that nearly one third of children ages 2-19 years are overweight (≥85th percentile), and 16.9% are obese (≥95% percentile). Childhood obesity has increased nearly 300% in approximately one generation (Ogden et al.).

Pediatric obesity and SB are associated with the entire gamut of somatic and psychological disorders (Daniels et al., 2005); one study found that 70% of 5-17 year-old obese children had at least one risk factor for cardiovascular disease, and nearly 40% had two risk factors (Freedman, Khan, Dietz, Srinivasan, & Berenson, 2001). Furthermore, SB, independent of other variables, is associated with several conditions such as hypertension, metabolic syndrome, and colorectal cancer in adulthood (Healy et al., 2008; Marchand, Wilkens, Kolonel, Hankin, & Lyu, 1997). Even more alarming is the fact that SB and pediatric weight disturbances are linked with early morbidity and death (American Heart Association [AHA], 2010; Barlow & the Expert Committee, 2007; Fontaine, Redden, Wang, Westfall, & Allison, 2003). Some have even speculated that the current generation of children may have a shorter life expectancy than their parents (AHA; Fontaine et al.).

While researchers have begun to recognize the importance of SB for acute and chronic problems in childhood (Freedman et al., 2001; Healy et al., 2008; Marchand et al., 1997), measuring, quantifying, and defining SB remain difficult (Bennett, Winters-Stone, Nail, & Scherer, 2006; Pate, O'Neill, & Lobelo, 2008). SB is not simply the opposite of physical activity (Olds, Maher, Ridley, & Kittel, 2010). Furthermore, SB is not the same as inactivity—which is completely passive behavior. On the contrary, many sedentary choices, such as video gaming and seated social conversation, require concentration or interactive responses from participants.

The number of studies addressing SB in children and adolescents continues to grow, but such research conclusions may have an unsure foundation without addressing the basis of defining and measuring SB and determining thresholds of SB conferring increased risk of obesity and chronic disease. This literature review therefore examines the theoretical and operational definitions of SB used in recent longitudinal studies that address pediatric health and weight, in order to guide future research.

Methods

Format of the literature search follows a protocol similar to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009). Peer-reviewed journal articles were retrieved using the PubMed, Google Scholar and CINAHL electronic search databases. PubMed was used because it indexes over 21 million citations from MEDLINE, science journals, and other various online materials that include article abstracts—a key source of identifying relevant studies. Google Scholar was used because of its ability to link citations that are not always indexed in other databases and because it provides links to sources that are available to subscribing institutions. CINAHL contains nursing and allied health literature. Articles were limited to those published in English between January 2006 and December 2011. Electronic searches were guided by inclusion of articles that addressed three core topics: children/adolescents, weight, and sedentary behavior. Searches required that all three areas be addressed and the following key words were used: pediatric, childhood (for children/adolescents), obesity or overweight (for weight), and sedentary, inactive or inactivity (for SB) and longitudinal. Articles were limited to studies that used a longitudinal format, since longitudinal studies are the highest level of observational study—observational being the most widely used design for evaluating SB. Unlike cross-sectional studies that find correlations between variables without assumptions of causality, longitudinal studies can begin to make inferences on the direction of causality, though admittedly they are not as powerful as intervention studies. Interventional studies, however, account for a minority of articles because of the difficulty in implementing a true sedentary intervention—in essence a true SB intervention would be a detraining study (Pate et al., 2008). Finally, because theoretical and operational definitions of SB should be robust *over time*, longitudinal studies were the preferred source of information.

Studies in which the average age of subjects at conclusion was above 21 years of age (not meeting the criteria of children or adolescents), were excluded, as well as studies not addressing the issue of overweight, articles focused on physical activity, flexibility, or genetics (not meeting criteria of sedentary behavior), and studies using interventions that were not longitudinal.

Two studies were found in the references of the articles retrieved that met all criteria, for a total of 13 articles that met selection criteria (see Figure 1).

Data from the 13 articles were organized based on study purpose, study length, sample size, age of subjects, measurement of obesity, theoretical and operational definitions of SB in the articles, basis for those definitions, and the way SB was measured—subjectively or objectively. Articles are presented in Table 1, sorted by ascending age of the participants.

Results

The studies were reported in a variety of different themed journals such as obesity (Bacha et al., 2010; Ekelund et al., 2006; Timperio et al. 2008), pediatrics (Bacha et al.; Blair et al., 2007; Metcalf et al., 2011; Nelson, Neumark-Stzainer, Hannan, Sirard, & Story, 2006; Timperio et al.; Ventura, Loken, & Birch, 2006), social work (Cecil-Karb & Grogan-Kaylor, 2009), preventative medicine (Fulton, Dai, Steffen, Grunbaum, Shah, & Labarthe, 2009), sport science (Aires et al., 2009; Hands, Chivers, Parker, Beilin, Kendall, & Larkin, 2011), and nutrition (Westerberg-Jacobson, Edlund, & Ghaderi, 2010). Only one article (Chen, Wall, Kennedy, Unniathan, & Yeh, 2007) was found in a nursing journal, and as far as could be determined, only that study had nurses affiliated with manuscript authorship. Five articles reported studies performed in the United States, while the other eight were studies conducted in New Zealand (Blair et al.), Australia (Hands et al.; Timperio et al.), England (Metcalf et al.), Portugal (Aires et al.), Sweden (Ekelund et al.; Westerberg-Jacobson et al., 2010), and Taiwan (Chen et al.)

All 13 studies had a study length of at least one year (range 1-8 years), and more than half had four years or more of longitudinal data. The age of subjects at baseline ranged from birth to 18 years-old. With the exception of one study (Ekelund et al., 2006), sample size was greater than 150; three studies had more than 1000 subjects. All but one study specified a weight measurement (such as body mass index or body fat percentage) adjusted for age and gender, an important factor when working with children (Nelson et al., 2006).

Theoretical Definitions of Sedentary Behavior. Theoretical definitions, i.e., explanations of the concept by use of subjective constructs, were most likely used to some degree in framing all of the studies; however it was not immediately clear in the reviewed articles what those definitions were. For example, one article did not explicitly state a theoretical definition of SB, but did say that social cognitive theory enhanced the understanding of sedentary behavior (Timperio et al., 2008). All of the articles gave reasonable background information to support researching SB to some degree, yet none overtly stated a conceptual meaning of sedentary behavior.

Operational Definitions of Sedentary Behavior. Operational definitions are used to model or quantify theoretical definitions. Four articles identified SB in terms of activity level (Blair et al., 2007; Ekelund et al., 2007; Hands et al., 2011; Metcalf et al., 2011). Three of these four articles defined SB in terms that could be objectively measured, all by accelerometry (Blair et al., Ekelund et al., Metcalf et al.). Of these three, one study identified SB using a definite cutoff value (100 counts/min) by accelerometry, but this was admitted to be an arbitrary cutoff value (Ekelund et al.). The other two studies did not identify a specific cutoff value, but derived metabolic equivalents (METs, a measure of the energetic intensity of an activity) from the counts/min (Blair et al.) or defined SB as behaviors that were not categorized as moderate-to-vigorous activity (Metcalf et al.). The last article using activity level as a definition of SB used a physical activity questionnaire that was completed by parents on various activities and the frequency of participation in those activities (Hands et al.).

Eleven articles used screen time as a definition of SB, though not all gave the exact amounts of screen time that would equate with SB (Aires et al., 2009; Bacha et al., 2010; Blair et al., 2007; Cecil-Karb & Grogan-Kaylor, 2009; Chen et al., 2007; Fulton et al., 2009; Hands et al., 2011; Nelson et al., 2006; Timperio et al., 2008; Ventura et al., 2006; Westerberg-Jacobson et al., 2010). Three articles used television-viewing time exclusively as the definition and measurement of sedentary behavior (Bacha et al.; Cecil-Karb & Grogan-Kaylor; Westerberg-Jacobson et al.). In addition to viewing television, watching videos and recreational computer use were specified as types of screen time. One study included reading as a SB (Fulton et al.).

Regarding the objectivity of SB evaluations, three studies objectively measured SB and all of these used accelerometers in the research (Blair et al., 2007; Ekelund et al., 2007; Metcalf et al., 2011). None of the studies explicitly stated using an objective protocol of SB to measure screen time. One study translated activity questionnaire responses into a physical activity score (Hands et al., 2011), and 11 studies used some form of screen time recall/questionnaire response to quantify sedentary behavior (Aires et al., 2009; Bacha et al., 2010; Blair et al.; Cecil-Karb & Grogan-Kaylor, 2009; Chen at al., 2007; Hands et al.; Fulton et al., 2009; Nelson et al., 2006; Timperio et al., 2008; Ventura et al., 2006; Westerberg-Jacobson et al., 2010). Subjective measurements were made by parental recall of the child's activities, were self-reported by the youth, or were a combination of both. Only two articles combined screen time and an activity component to measure sedentary behavior (Blair et al.; Hands et al.). Only one study combined objective and subjective measures, but this study defined SB by accelerometry and addressed screen time as a separate variable (Blair et al.). None of the studies used objective measurements for screen time and an activity component combined.

Rationale for Definitions. One study referred to a theoretical model (social cognitive theory) to rationalize the understanding and definition of sedentary behavior (Timperio et al., 2008). Hands et al. (2011) was the only study to cite national or international recommendations in support of the definition of SB used in the research.

Discussion

Links between SB and obesity-related chronic disease increase the need for research regarding the health effects of specific levels of SB in children and adolescents. Unfortunately, definitions of SB in research literature have varied broadly, from simply time spent watching television to conversion of accelerometry data into METs. This review revealed that little consensus exists between studies, and when there is consensus, the studies fail to identify cutoff values. For example, of the studies that used screen time to operationalize SB, few indicated cutoff values for acceptable versus excessive screen time (Bacha et al., 2010; Blair et al., 2007; Cecil-Karb & Grogan-Kaylor, 2009; Fulton et al., 2009; Hands et al., 2011; Nelson et al., 2006; Timperio et al., 2008; Ventura et al., 2006; Westerberg-Jacobson et al., 2010). Furthermore, four studies included computer time as an indicator of SB, but one, Fulton et al. (2009), did not limit computer time to recreational use and included reading in the measurement of sedentary behavior (Nelson et al.; Timperio et al.; Ventura et al.). Similar to these findings, a recent review of intervention studies found discrepancies and difficulties in defining what it means to be sedentary (Bennett et al., 2006).

Theoretical Grounding. Framing the right research design requires framing the right questions for study. The proper questions must be selected based on some method of organizing and explaining measured outcomes. Theories provide the basis for research, and omitting to mention or refer to the theoretical underpinnings was a deficit in the studies examined. Only one article in this review cited a theoretical basis for investigating sedentary behavior (Timperio et al., 2008). Research should not only include theoretical underpinnings but also the rationale for using the instruments and measurements selected. The current review found one study (Timperio et al., 2008) that used a theoretical rationale (social cognitive theory) and one (Hands et al., 2011) using an operational rationale (Australian recommendations).

Physiological Concepts in Sedentary Behavior. Current studies also fail to bring physiological concepts to the table when finding grounding for research. Although some studies determined operational cutoff values for defining SB, broader physiological concepts were not integrated. Theoretical frameworks explain more about behavioral choices rather than the actual measure of the behavior. For example, the Theory of Planned Behavior explains a modest, but significant, amount of SB choices in late adolescents (Rhodes & Blanchard, 2008), yet quantifying this relies on equations like calculating total daily energy expenditure (TDEE) as a composite of resting metabolic rate, the thermic effect of food, and the thermic effect of activity. Total daily energy expenditure is an integral concept to SB, with studies supporting that non-exercise activity (of which SB is a part) accounts for the majority of activity thermogenesis

(Donahoo, Levine, & Melanson, 2004). Although TDEE is especially important in considering SB, other physiological constructs must be utilized appropriately in planning the reasons and goals of SB research.

National and International Objectives. In general, most national and international organizations inadequately define sedentary behavior. Inconsistencies in national and international classifications of SB contribute to the difficulty in defining sedentary behavior. Organizations should provide more clarity on their definitive conceptualization or measurement of sedentary behavior to help laypersons and researchers to unify understanding and assessment. Most organizations define SB in terms of what it is not (physical activity) instead of what it is (a distinct set of low-energy behaviors). Only one study cited national organizational guidelines, and even this study did not provide a cutoff value (Hands et al., 2011). No American study cited national organizational guidelines, such as the American Academy of Pediatrics' (2001) statement or the AHA's (2010) recommendations to limit television viewing to no more than 2 hours per day. Thus, even when organizations have definitions for SB, they are not being cited in the longitudinal pediatric literature.

Definitions of Sedentary. The word *sedentary* comes from Latin "sedere" meaning "to sit" which is not the same as inactivity (Olds et al., 2010). Although in the literature screen time predominates as one of the behaviors that is most sedentary, consideration of actions that do not sufficiently raise resting energy expenditure is important. Pate et al. (2008) conceptualized SB as any activity that does not significantly raise resting energy expenditure, such as sleeping, sitting, and screen time. Operationally, this conceptualization includes behaviors that are equivalent to 1.0-1.5

METs (Pate et al.). While this definition helps bring clarity to SB, the definition could include sleep, which can be a distinctive restorative process with measurable metabolic benefits to the body (Van Cauter, Spiegel, Tasali, & Leproult, 2008). However, restorative sleep often measures below 1.0 METs and thus would not be included when considering the operational definition of sedentary behavior. Therefore, the proposed unifying definition of SB is: any activity that does not significantly increase resting energy expenditure (theoretical definition), equating to all behaviors from 1.0-1.5 METs (operational definition). Furthermore, to help increase the awareness of SB definition and recommendations, it would be helpful to couple the definition of SB with physical activity guidelines. A plausible solution for joining the two concepts is given in Table 2. Furthermore, researchers should integrate physiological concepts applying this definition of SB to help guide the study design.

Implications for Nursing. Childhood lifestyles are becoming increasingly sedentary with the average child engaging in less than 60 minutes of physical activity a day and participating in more than 40 hours of screen time per week (AHA, 2010). As SB becomes more prevalent among youth, establishing definitions and criteria is imperative to provide further definition to expected outcomes from modification of SB in an individual and ultimately to promote wellness, prevent adverse effects, and reverse detriments. Limitations of this systematic literature review include a narrow focus on only longitudinal studies. However, the results of this review are similar to other findings on the dilemma of defining sedentary behavior (Bennett et al., 2006; Pate et al., 2008). Further research is essential to determine what behaviors comprise SB and what effects these behaviors have on childhood weight and health.

This literature review has important implications specific for nursing practice, education, and research. Nursing is one of few professions that provide care to pediatric clients with problematic sedentary behavior. From acute care to public health and school health care, nurses constantly confront the challenges that SB causes in youth. In practice, nurses must join in the effort to apply the proposed definition of SB and deter its deleterious effects. Educating patients and fellow health care colleagues on the difference between SB and physical activity will increase understanding and support for targeted interventions on both fronts. With regard to research involvement, nurses do not necessarily need to participate in research studies to advance the science. Rather, finding opportunities to stay current on the state of research in this field and putting the best evidence into practice fills this need. Moreover, success in this area will most likely be achieved when an interdisciplinary approach is taken. Since nurses are often the gatekeeper between multiple professions of patient care, nurse involvement in this issue is essential in providing superior care for long-term healthy outcomes.

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Figure 1. Search and Selection Process

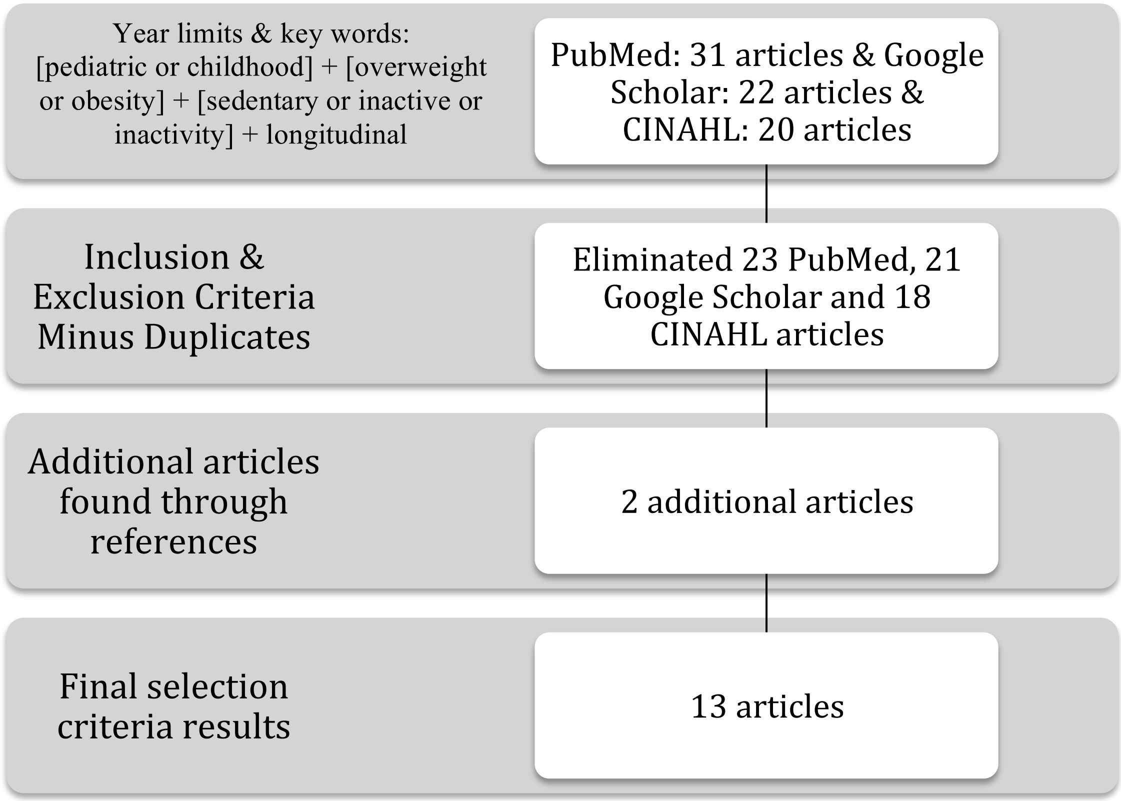

Table 1. Longitudinal Sedentary Behavior Studies Listed by Age, Jan 2006 - Nov 2011

Authors & Year	**Purpose**	**Study Length**	**Sample**	**Baseline Age Mean (Range)**	**Obesity Measurement**	**Theoretical definition of sedentary**	**Operational definition of sedentary**	**Rationale for definition**	**Measures of SB**
Blair et al. (2007)	Determine the effect of selected factors, most modifiable, on obesity in New Zealand children	7 years	591 subjects at last follow up	Birth (--)	International gender and age specific BMI range and body fat %	Not defined	<3 METs as determined by accelerometry. TV viewing is measured separately and nowhere is it referred to as a SB	--	Subjective and objective
Hands et al. (2011)	Relationship between BMI, PA and screen time in children and adolescents	8 years	1403 subjects	6 (--)	BMI and BMI percentile	Not defined	6 y/o: TV viewing (≥2 hrs) & club/sport involvement 8 y/o: TV viewing (≥2 hrs) & club/sport involvement 10 y/o: TV viewing (≥2 hrs) & lowest tertile of total activity/week 14 y/o: TV viewing (≥2 hrs) & lowest tertile PA score	Screen time based on Australian recommendations for adolescents	Subjective
Metcalf et al. (2011)	Determine if SB begets adiposity, or vice versa	3 years	202 subjects	6.9 (--)	BMI SD-score, waist SD-score, body fat %	Not defined	Implied that SB is <MVPA (by accelerometry)—counts/min cutoffs not identified	--	Objective

BMI = Body Mass Index, MET = Metabolic Equivalent, MVPA = Moderate to Vigorous Physical Activity , PA = Physical Activity, SB = Sedentary Behavior, -- = Information not stated

Authors & Year	Purpose	Study Length	Sample	Baseline Age Mean (Range)	Obesity Measurement	Theoretical definition of sedentary	Operational definition of sedentary	Rationale for definition	Measures of SB
Ventura et al. (2006)	Factors in adolescent metabolic syndrome	8 years	154 subjects (girls only)	7 (--)	BMI percentile by age and gender	Not defined	TV viewing and computer time	--	Subjective
Chen et al. (2007)	Predictors of increased BMI in Chinese children	1 year	307 subjects	7.5 (7-8)	BMI and BMI percentile	Not defined	TV viewing time, and video and computer gaming time	--	Subjective
Bacha et al. (2010)	Safety of neighborhoods affecting SB and BMI	2 years	868 subjects	-- (3^{rd}– 5^{th} grades)	BMI z-score	Not defined	TV viewing time	--	Subjective
Timperio et al. (2008)	Family and home environment influences on BMI	3 years	344 subjects	-- (10-12)	BMI z-score, used international gender and age specific cutoffs	Not defined but related understanding SB to Social Cognitive Theory	TV viewing, video gaming and recreational computer time	Social cognitive theory	Subjective
Cecil-Karb & Grogan-Kaylor (2009)	Safety of neighborhoods affecting SB and BMI	6 years	5886 subjects	12 (5-20)	BMI and BMI z-score	Not defined	TV viewing time	--	Subjective

BMI = Body Mass Index, MET = Metabolic Equivalent, MVPA = Moderate to Vigorous Physical Activity , PA = Physical Activity, SB = Sedentary Behavior, -- = Information not stated

Authors & Year	Purpose	Study Length	Sample	Baseline Age Mean (Range)	Obesity Measurement	Theoretical definition of sedentary	Operational definition of sedentary	Rationale for definition	Measures of SB
Westerberg -Jacobson et al. (2010)	Lifestyles and eating patterns of girls and the ideation of thinness	5 years	593 subjects (girls only)	Four cohorts: 9.5, 11.4, 13.4, & 15.4 Overall: 12.2 (8-16)	International gender and age specific BMI	Not defined	TV viewing	--	Subjective
Fulton et al. (2009)	Relationship between PA, SB and dietary intake on BMI and fat mass	4 years	472 subjects	Three cohorts: 10.4, 11.5, & 14.4 (--)	BMI, body fat %, fat mass index, fat-free mass index	Not defined	Time spent for TV viewing, reading, and computer use	--	Subjective
Aires et al. (2009)	Test various PA and SB measures on longitudinal changes in BMI	3 years	345 subjects	14 (11-16)	BMI	Not defined	TV viewing time and computer use time	--	Subjective
Nelson et al. (2006)	Trends in MVPA and SB in adolescents	5 years	2516 subjects	15.8 (11-18)	Not reported	Not defined	Limited to TV & video viewing and recreational computer time	--	Subjective
Ekelund et al. (2007)	Predict weight and fat in overweight, normal weight youth using PA and energy expenditure	4 years	13 obese, 15 non-obese	Obese: 17.5 (--) Non-obese: 17.7 (--)	BMI, fat mass, fat-free mass, body fat %	Not defined	<100 counts/min by accelerometry, acknowledged as arbitrary cutoff value	--	Objective

BMI = Body Mass Index, MET = Metabolic Equivalent, MVPA = Moderate to Vigorous Physical Activity , PA = Physical Activity, SB = Sedentary Behavior, -- = Information not stated

Table 2. Potential Format for Joining Physical Activity and Sedentary Behavior Definitions, or the F.I.T. and F.I.T. Principle

	Physical Activity	**Sedentary Behavior**
Frequency	≥ 20-30 min/session	< 1 hour/session
Intensity	Moderate-to-Vigorous	METs 1.0-1.5
Time	≥ 1 hour/day total	< 2 hours/day total
Family Responsibility	Safety	Limit screen time
Individual Responsibility	Enjoyable activities	Diversify activities
Types of activities	Sweat and/or breathe hard	Reading, face-to-face interactions, avoid screen time

Chapter 4: Manuscript 2 – Inclinometer Validation and Sedentary Threshold Evaluation in Older Adolescent University Students

Target journal for submission: Research in Nursing and Health

Inclinometer Validation and Sedentary Threshold Evaluation in Older Adolescent University Students

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Abstract

Sedentary behavior is a major contributing factor to obesity and significant morbidity and mortality in adolescence and into adulthood. The purpose of this study was to assess the accuracy of the ActiGraph GT3X+ device in measuring sedentary behavior and physical activity in older adolescent university students using the methods of inclinometry and accelerometry while: lying, sitting, reading, gaming, video watching, seated conversation, standing, stationary biking, and walking. Overall, accelerometry is superior to inclinometry, depending on the setting evaluated. Nevertheless, each device may detect specific behaviors more accurately. The findings support use of the ActiGraph GT3X+ in accurately measuring sedentary behavior. Additional research would be beneficial in improving inclinometer and accelerometer methods for measuring sedentary behavior and physical activity.

Inclinometer Validation and Sedentary Threshold Evaluation in Older Adolescent University Students

Sedentary behavior (SB) is an emerging field of interest, particularly because of its implications related to obesity, acute and chronic disease development, and early mortality (Daniels et al., 2005; Fontaine, Redden, Wang, Westfall, & Allison, 2003; Freedman, Khan, Dietz, Srinivasan, & Berenson, 2001; Ogden, Carroll, Kit, & Flegal, 2012). Daily amounts of SB have risen to a staggering proportion, particularly with the pre-adult populations (American Heart Association [AHA], 2011). Older adolescents and young adults experience 30-40 or more hours per week of SB, while most do not meet recommended physical activity guidelines (Nelson, Story, Larson, Neumark-Sztainer, & Lytle, 2008).

Although SB is part of the continuum of behavior and activity ranging from sedentary to light, moderate, and vigorous physical activity, SB plays its own, unique role in health regardless of other factors including exercise. For example, the impact of SB on health is significant on cardiovascular health, independent of physical activity (Healy et al., 2008). Furthermore, independent of other variables, SB is linked with metabolic syndrome, hypertension, and colorectal cancer in adulthood (Healy et al., 2008; Marchand, Wilkens, Kolonel, Hankin, & Lyu, 1997). Because of its independent importance, defining and measuring SB is critical to accurately determining its effect on the health of individuals.

Objectively quantifying SB is difficult because of its low activity level and the ubiquity with which it fills the lives of all. As a result, incorporating valid and reliable measurements will improve the ability of health professionals to estimate the outcomes and provide a means of discovering future interventions to determine appropriate levels of SB and maximize good health and longevity (Bennett, Winters-Stone, Nail, & Scherer, 2006; Freedson, Pober, & Janz, 2005; Pate, O'Neill, & Lobelo, 2008; Sasaki, John, & Freedson, 2011). Currently, accelerometry is the standard for objectively measuring SB and is used for national research such as National Health and Nutrition Examination Survey (NHANES). Accelerometers use counts per minute (cpm) as a method of measurement, similar to steps per minute for pedometers. A "count" is simply an amount of movement and speed in a particular direction. Most accelerometers only have one axis to measure movement, the vertical up and down direction (Y-axis). Some newer accelerometer models can now measure movement in all directions, having X, Y, and Z axes. In the older adolescent population of 18 years-old and older, SB has been defined as less than 100 cpm using the single, Y-axis only accelerometers (Troiano et al., 2008).

One possible new method of measuring SB is by body position using a device called an inclinometer. The inclinometer is new technology that appears to have some supporting validation (Carr & Mahar, 2012). Because lying and sitting positions have been previously described as sedentary (Pate et al., 2008), measuring SB by detecting these positions through body incline may prove useful. Additionally, the older but more prevalent tool of accelerometry is widely used for assessing SB by amount of body movement.

Standardized cut points for defining sedentary and physically active behaviors by accelerometry have been used for NHANES, which includes the older adolescent population (Troiano et al., 2008). However, most thresholds were established using older technology that only utilized the single, up and down axis. Upgrades in technology now incorporate measuring movement in three dimensions and combining the data into a single vector, a method called vector magnitude. Minimal research exists that determines the threshold between sedentary and non-sedentary behavior using the vector magnitude. For example, although the typical accelerometry cutoff for SB is <100 cpm (Treuth et al., 2004; Troiano et al., 2008), there is evidence that a higher threshold is more accurate (Romanzini, Petroski, Ohara, Dourado, & Reichert, 2012) such as <150 cpm (Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011). A higher threshold would make sense when using the vector magnitude since it gathers data from three axes, rather than a single axis.

Conceptual Model

Theoretical frameworks provide a systematic way of approaching constructs and understanding how they relate to one another (Glanz, Rimer, & Viswanath, 2008). Various theoretical frameworks and models for describing and studying SB that are dependent on the research focus. For the purposes of this research, a theoretical basis that could explain SB as a whole, as well as identify how to measure specific behavior, was requisite. The Theory of Planned Behavior (TPB), as described by Ajzen (1991), is one such theory that can explain both the overall process of engaging in sedentary behavior choices and also stipulates specific components for measuring the target behavior.

The TPB as posited by Ajzen (1991) relates behavior choices directly to an individual's intentions; attitudes, subjective norms, and perceived behavioral control influence individual intentions. This theory was shown to explain leisure choices in adolescents (Ajzen & Driver, 1991) such as sedentary behavior (Rhodes & Dean, 2009).

Numerous studies have used the TPB to investigate activity-related behaviors in adolescents (de Bruijn & van den Putte, 2009; Rhodes & Blanchard, 2008) including older adolescent college students (Wing Kwan, Bray, & Martin Ginis, 2009).

The TPB explains and predicts behavior choices at the individual level. The TPB explained a modest, but significant, amount of SB choices in older adolescents, typically ranging from r=0.20 to 0.39 (Rhodes & Blanchard, 2008). However, self-reported questionnaires were the main source of these statistics. If an objective method of measuring SB is reliable and valid, this may improve the explanation of each step in the TPB, and/or may indicate ways to adapt the TPB and better explain SB among older adolescents.

The intent of this study was to focus on accurately measuring engagement in SB as the target behavior (see Figure 1). Measuring behavior is essential in the TPB and it consists of four elements: the *action*, the target *population* at which the action is directed, the *context*, and the *time* at which it occurs (Ajzen & Fishbein, 1980). For the purpose of this study, the actions measured were sedentary behaviors, the target population was older adolescent college students, and the context was routine, everyday activities (within the laboratory setting). Once there are accurate and precise measurements of SB in controlled settings, researchers can then use these techniques to measure these behaviors in natural environments involving free-living conditions. The purpose of this study was to establish the validity of the ActiGraph GT3X+ inclinometer and accelerometer using both single and triple axes methods with thresholds of 100 cpm and 150 cpm to distinguish sedentary from non-sedentary behaviors using the Theory of Planned Behavior (Ajzen, 1991) as a foundation.

Methods

Power Analysis

The computation of power analysis used the computer program nQuery (Statistical Solutions, Ltd., Los Angeles, CA). Sample size estimate was based on the number of participants used in similar research and following general consensus on principles of statistics (Harrell, 2001). Estimates using the program nQuery for an effect size of 0.5 with 80% power and an α of 0.05, recommended a minimum of 18-23 subjects, and general statistical principles advocated for approximately 20 subjects. Therefore, in order to account for attrition, the goal was to recruit 25-30 participants.

Sample

The target population included older adolescent students of varying socio-demographic backgrounds and body sizes. Study participants included a convenience sample of 18- to 20-year-old undergraduate students enrolled at a large public university in the Mid-Atlantic region. Once Institutional Review Board approval was granted for the study, participants were recruited through flyers, word-of-mouth, and electronic university announcement emails sent by various departments to the appropriate age group of students.

Recruitment inclusion criteria included older adolescent males and females aged 18- to 20-years-old able to wear the ActiGraph GT3X+ device and perform the following activities: lie down, sit, read a book while seated, play a video game, watch a video, engage in seated conversation/talk on the phone, stand, pedal on a stationary bike, and walk unassisted. Exclusion criteria included those unable to perform the aforementioned activities, non-English speakers, and those with any type of lower body injury or condition such that performing the activities was difficult, worsened the condition, or significantly altered the participant's ability to perform the behaviors. For example, any potential participant who was otherwise healthy, but used crutches, was not eligible.

Location

The study location was private, within an exercise physiology laboratory, in a research center focused on healthy youth development. There were nine stations for each of the tested behaviors: lying down, sitting, reading a book while seated, playing a video game on a computer, watching a video, engaging in seated conversation/talking on the phone, standing, pedaling on a stationary bike, and walking. Although completion of the entire series of nine behaviors occurred in the same laboratory, participants moved from station to station for testing each behavior. The first six behaviors received a designation of typical, everyday SB, and the order changed from one participant to the next participant. The order of the last three behaviors also rotated from participant to participant.

Instruments and Measures

After obtaining informed written consent, and following a standardized protocol of a larger study, participants were weighed twice to the nearest 0.1 pound using a digital scale (Seca Scale Robusta 813, Birmingham, UK) and an average of the two measures was used. Similarly, participants were measured twice using a stadiometer (Shorr Height Measuring Board, Olney, MD) to the nearest 0.1 cm and an average of the two measures was used. Finally, waist circumference was averaged using two measures with a Lifetime Tape Measure (Prym-Dritz Corp, Spartanburg, SC) taken at the level of the iliac crest, just below the umbilicus to the nearest 0.5 cm.

Since both inclinometry and accelerometry data come from the same device, the study employed only the single ActiGraph GT3X+. Participants wore this instrument at the level of the waist, secured with an elastic band and buckle, placed over the right hip. Participants completed each of the nine behaviors for five minutes each, with a one to two minute break between activities.

Sedentary Behaviors

The investigator reviewed the protocol instructions for each behavior with participants before beginning and reminded participants to perform the behaviors as they would at home or school. The following section describes the participant's positioning for each behavior.

Lying down. Participants were in the supine position on a padded laboratory exam table with pillow support for the head, were to lie quietly and were not allowed to sleep.

Sitting. Participants sat in a comfortable, padded, non-mobile upright chair for measuring the sitting behavior. Participants were able to move and shift positions as long as they remained seated.

Reading. The reading behavior was done in the same fashion as the sitting behavior, with participants sitting at a table and having the option of reading Harry Potter or one of their own books, be it a text or leisure book.

Gaming. Participants played a free, popular online game—requiring minimal instruction and needing only the mouse to operate—using a desktop computer. Seating was similar to the sitting behavior criteria.

Watching. Participants viewed a short, five-minute digitally animated film on a laptop computer. Participants sat in the same manner as above.

Talking. While seated, participants had the option of talking on their personal cell phone or having a casual conversation with the researcher.

Standing. Participants were required to stand for the duration of the testing period without moving, although they could shift positions as needed.

Physical Activities

Biking. Participants used a Monark 868 stationary bike (Monark Exercise, Sweden) at moderate intensity for this activity. Moderate intensity was equivalent to speeds between 50-60 rpm, while maintaining a workload of approximately 100 W. Seat and handle bar height were adjusted as needed for each participant. Participants were required to stay within the moderate intensity limits and remain seated for the duration of the testing.

Walking. A Quinton Q65 treadmill (Quinton Instrument Co., Seattle, WA) was set to a speed of 3.0 miles per hour with no incline for participants to complete the walking activity. Participants were not allowed to hold to the side or front handlebars and were to maintain a natural walking gait.

Of the nine behaviors measured in the study, two were explicitly active by design: riding a stationary bike and walking on a treadmill. Riding the stationary bike had particular interest for this study, since pedaling at a moderate intensity is active; yet participants riding the stationary bike were in the seated position. Therefore, this activity determined whether both inclinometry and accelerometry could accurately detect this form of seated exercise. Walking on a level treadmill at 3.0 miles per hour served as a standard for active behavior.

Demographic measures

Participants completed a simple, one-page, 5-item form gathering simple demographic information which elicited gender, age, semesters completed at school, race/ethnicity, and listing of extracurricular activities.

Instrument

The ActiGraph GT3X+ (ActiGraph, LLC, Pensacola, FL) device assessed activity by inclinometry and accelerometry. The GT3X+ is a small, unobtrusive, and essentially tamper resistant device which is well-tolerated by older adolescents and does not hinder activity (ActiGraph, 2013; de Vries, Bakker, Hopman-Rock, Hirasing, & van Mechelen, 2006). The GT3X+ houses both an accelerometer and inclinometer, weighing only 19 grams (ActiGraph, 2013). The inclinometer data is categorical and coded as lying, sitting, standing, or off. Accelerometry is captured in 3 axes and expressed in terms of cpm. The ActiGraph GT3X+ collected data at 30 Hz and then aggregated the data during the post-collection processing stage into 10-second epochs. The accelerometry feature of the GT3X+ is highly precise with sedentary behaviors in both laboratory (Carr & Mahar, 2012; Sasaki et al., 2011) and in free-living conditions (Kaminsky & Ozemek, 2012; Santos-Lozano et al., 2012) according to accepted standards (Landis & Koch, 1977). Direct observation of all behaviors by the researcher provided a validating measurement criterion.

The GT3X+ accelerometer's construct validity is high, typically ranging r=0.39-0.90 (de Vries et al., 2006) or, specifically to SB, between 80-98% agreement with direct observation (Carr & Mahar, 2012; Hänggi, Phillips, & Rowlands, 2013). Only one study, using a group that included older adolescents, has investigated the construct validity of the GT3X+ inclinometer, which found 63-67% agreement with direct observation (Carr & Mahar, 2012). Several studies supported criterion validity in comparison to the older accelerometer model (De Vries et al., 2006; Kaminsky & Ozemek, 2012; Sasaki et al., 2011).

Sedentary was defined as lying or sitting positions for the inclinometer method (standing was accepted as the appropriate code for the standing activity). Accelerometry data aggregation included two methods. First, the standard single-axis only (Y axis) method was applied, using cut points at both 100 cpm (Axis100) and 150 cpm (Axis150) to determine sedentary versus active behavior. Because the accelerometer gathers movement data in three dimensions, a vector calculation used all three axes. Thus, for the second method, vector magnitude calculations compared both the 100 cpm (VM100) and 150 cpm (VM150) cut points for sedentary behavior. Both cut points of <100 cpm and <150 cpm for SB is supported in the literature, and thus comparing accuracy of these two with this study was desirable (Kozey-Keadle et al., 2011). Utilizing the low-frequency extension option for the accelerometer improved detection of low-frequency movement; SB fits into this category.

The following is a summary of the methods:

a) Inclinometer—uses inclinometer measurement only, with a sedentary definition of lying and sitting positions,

b) Axis100—uses the single axis measure only (Y axis) with a sedentary definition of <100 counts/minute, and

c) Axis150—uses the single axis measure only (Y axis) with a sedentary definition of <150 counts/minute,

d) VM100—uses the vector magnitude combining X-Y-Z axes, with a sedentary definition of <100 counts/minute,

e) VM150—uses the vector magnitude combining X-Y-Z axes with a sedentary definition of <150 counts/minute.

Statistical analyses

Statistical analyses were performed using SPSS 22.0 (IBM Corp., Chicago, IL). The five methods (inclinometer, Axis100, Axis150, VM100, VM150) were compared against the criterion of direct observation by the researcher. Accuracy was the percent agreement of time against the criterion measure of direct observation, as noted by the researcher. The researcher calculated the 95% confidence interval for the mean, correctly coded for body position and amount of movement.

Results

Overall, of the 28 participants who elected to do the study (12 male, 16 female), every one completed the study in its entirety. There were no device failures and all had 100% usable data. A summary of the sample demographics appears in Table 1. The sample was 57.1% female, and was evenly split among 18 (28.6%), 19 (32.3%), and 20 (32.1%) year-olds. Of the sample, 25.0% were non-white or mixed ethnicity. The mean BMI was 22.8 (*SD*=3.1) kg/m^2. By gender, the mean waist circumference was 86.6 (*SD*=9.1) cm and 84.2 (*SD*=7.7) cm, for males and females, respectively. Seven (25.0%) participants were overweight when considering either BMI (≥25.0 kg/m^2) or waist circumference (≥102 cm for males, ≥88 cm for females).

In considering the mean percentage of time that was coded correctly (Table 2), the accelerometry data outperformed the inclinometry data in every category except for walking (which was correctly coded as active 100% of the time across all the measurement methods) and using the stationary bike in the case of the vector magnitude methods (VM100 and VM150). The inclinometer varied in accuracy from a low of 44.9% during video gaming to a high of 100% for walking. With the exception of the stationary bike activity accuracy, which was 54.8% and 48.8% for the Axis100 and Axis150 methods, respectively, accuracy ranged from 98.8% to 100%. Both vector magnitude methods had perfect accuracy for active behaviors, and otherwise sedentary accuracy ranged from ≥90.5% for the VM100 method and ≥95.2% for the VM150 method. Full details of accuracy of the five methods on each behavior are reported in Table 2.

With respect to the seated stationary bike, the inclinometer accurately detected a sitting position 27.0% (95% confidence interval [CI]=14.1-40.0%) of the time. When accepting the "standing" code as active (or non-sedentary), the accuracy jumps to 73.0% (95% CI=60.0%-86.0%). These differences affected the inclinometer's active and overall accuracy. When considering body position, active accuracy of the inclinometer drops to 63.5% (95% CI=57.1-70.0%), with an overall accuracy of 65.8% (95% CI=59.9-71.8%). When considering sedentary versus non-sedentary behavior, active accuracy of the inclinometer improves to 86.5% (95% CI=80.0-92.9%), with an overall accuracy of 70.9% (95% CI=65.0-76.9%)(Table 3). In assessing sedentary versus active behavior as the primary endpoint, the inclinometer had a lower accuracy than any of the accelerometer settings in detecting sedentary activity, but a similar accuracy to the

Axis100 and Axis150 settings in detecting activity. Overall accuracy was lower for the inclinometer compared to any of the accelerometer settings (Table 3).

Discussion

The aim of this study was to determine the accuracy of the ActiGraph GT3X+ in discriminating sedentary from non-sedentary behaviors in terms of both inclinometry and accelerometry within the parameters of measuring behavior specified by the Theory of Planned Behavior (Ajzen, 1991). The results support the GT3X+ as an accurate device for measuring SB and, in general, accelerometry outperforms inclinometry for measuring SB and in overall correctness or accuracy. Considering sedentary accuracy, single axis and using the 150 cpm cutoff methods were superior. Axis150 had an impressive 100% accuracy, Axis100 was similar at 99.7%, VM150 was 97.1%, VM100 was 94.4%, and the inclinometer was 66.5%. However, when considering ability to detect non-sedentary behaviors, both VM150 and VM100 were at 100%, with inclinometry accuracy at 86.5%, and Axis100 77.4%, and Axis150 74.4% (see Table 3).

The stationary bike activity played a major factor in the accuracy of the methods, particularly with the single axis (Axis100, Axis 150) methods. Both vector magnitude methods detected biking as an active behavior 100% of the time, while the single axis methods were only 54.8% (Axis100) and 48.8% (Axis150) accurate. The discrepancy between the two methods probably lies in the fact that minimal up and down (Y axis) movement occurs during seated biking, yet there may be more side to side (Z axis) or forward and back (X axis) movement that the participant does to maintain speed and momentum of pedaling. Any activity done while sitting is similar, since the very nature of sitting would take away or limit the factor of the vertical axis in contributing to the overall activity detected by the device. Using three axes rather than a single axis for detecting SB and physical activity is still relatively new, particularly in the younger age groups, and as yet has had mixed results and needs to be researched further (Freedson et al., 2005; Howe, Staudenmayer, & Freedson, 2009).

Determining the superiority of single axis or triple axis accelerometry data would benefit research in the area of SB and physical activity (Freedson et al., 2005). This study would suggest that the use of the multi-axial, or vector magnitude, data may be better than single axis measurements. This is true particularly with seated, but active, behaviors when considering clinical significance, although statistical significance was nearly met when considering the 95% confidence interval between VM150 (97.8%, 95% CI 96.1-99.4%) and Axis150 (94.3%, 95% CI 92.2-96.4%).

The inclinometer's ability to accurately detect biking is mixed and depends on the output that the researcher is studying. Per the manufacturer's design, once the GT3X+ device registers a high enough movement threshold (6 counts per second), the inclinometer output will automatically code as standing (Hawk, 2012). This feature explains why the inclinometer's walk accuracy (100%) is better than the stand accuracy (93.7%). If the intent of the research is to distinguish between sedentary versus active behaviors, this design element is beneficial, as it will default to the standing output regardless of the actual incline. However, if detecting body position were the ultimate goal, this feature would prevent an accurate measurement. For example, when registering body incline, the inclinometer was only 27.0% accurate for detecting the sitting position while participants used the stationary bike. However, this accuracy jumps to 73.0% when adjusting for the fact that the standing position was considered active for that particular behavior. This too, has its drawbacks, since using “standing” as a default code for “active” would have the effect of categorizing the test of standing in place as being active, when in reality this expends very little energy. However, most people likely do not stand perfectly still or in a single spot for long periods. In fact, standing has been considered by some as non-sedentary as it may contribute to improved insulin and lipid management simply by not having the body in the lying or sitting sedentary positions (Duvivier et al., 2013). Considering these two dilemmas, the future use of the inclinometer likely plays a role when analyzing inclinometer and accelerometer data together, since integrating the two would resolve dual issues of “sitting but active” and “standing but sedentary.”

The results of this study validated the ActiGraph GT3X+ accelerometer. However, the current literature is wrought with discussion on whether single-axis versus vector magnitude is the best method for measuring sedentary and activity level (Freedson et al., 2005; Howe et al., 2009). Furthermore, the thresholds for SB and the various levels of physical activity differ depending on the population of interest (Freedson et al., 2005; Kozey-Keadle et al., 2011; Mattocks et al., 2007; Troiano et al., 2008; Trost, Loprinzi, Moore, & Pfeiffer, 2011). With respect to the inclinometer, although it had high (86.5%) accuracy for detecting active behaviors, its method of coding makes it unable to discriminate light, moderate, or vigorous activity as all of these would be coded as “standing”. Thus, the best use of the inclinometer is to detect body position or in conjunction with accelerometry data when assessing both sedentary and physical activity levels.

Additional findings of this study demonstrate the difficulty in finding new objective measures of sedentary behavior. While the inclinometer has the potential to help define behaviors in terms of body position, its use as the sole measure of SB should be judicious. The ability to calibrate the angles that the inclinometer uses to define the lying, sitting, and standing positions could likely improve the output of the device. Additionally, combining its data with that of the accelerometer may give additional insight into what constitutes SB and physical activity.

Limitations

Limitations of this study include a relatively small, mostly Caucasian sample. Results are not generalizable beyond the age ranges examined in this study. In addition, the study examined more SBs than active behaviors, and was limited to discriminating typical lying and sitting behaviors against walking and biking. Body positioning during the behaviors may not have always been the natural position since participants were not in their free-living condition. Increasing testing time may have given a more accurate perspective on SB as participants "settle in" to their environment and the behavior being tested. Also, the behaviors tested may not be typical of SB in every population. Lastly, there was not a full discrimination between SB and light physical activity. However, validating the cutoff points for light, moderate, and vigorous physical activity was not an objective of this study. Rather the aim was to discriminate SB from routine physical activities predominantly used in the older adolescent student population.

Implications

This study has expanded the knowledge of objective measurement of sedentary behavior. The technology of inclinometry is relatively new, yet has demonstrated potential in measuring SB using body position as criterion. This research concluded that the ActiGraph GT3X+ inclinometer feature is approximately 70% accurate in determining sedentary versus non-sedentary behavior overall, which is congruent with another inclinometer study (Carr & Mahar, 2012). Rigorous scientific research could further improve the inclinometer by validating categorization of the angles of lying, sitting, and standing. An option to adjust these angle definitions through ActiGraph's software could allow for correcting incline data to the target population, though accurately determining activities such as bicycling could continue to be problematic. Body position has been implicated as a strong factor in determining what is defined as sedentary (Pate et al., 2008). Therefore, the inclinometer has great potential for future use in measuring sedentary behavior. Additionally, as long as it does not rely on constant body movement to gather data, like the accelerometer, the inclinometer could become a good way to detect low-threshold behaviors, which sedentary behavior dominates.

Additional research is needed to help define appropriate sedentary, light, moderate, and vigorous activity in terms of the three-dimensional movement (Sasaki et al., 2011). As vector magnitude is a relatively new way of analyzing accelerometry data, future studies should be clear about data processing and whether single-axis or vector magnitude was the selected method. This ultimately will influence the choice of activity cutoffs, such as the 100 versus 150 cpm threshold decision on sedentary behavior.

Summary

In summary, there is a need to establish objective measurement standards for sedentary behavior. There is a need for additional validation of novel methods of measuring SB before generalized use in research. The inclinometer is moderately accurate overall, and could be improved with additional testing and calibration. Accelerometry remains a good standard by which to measure sedentary behavior. However, clarity and refinement of appropriate thresholds for SB, and light, moderate, and vigorous physical activity needs additional appraisal across all age groups as three-dimensional movement data becomes the standard. Therefore, as technology constantly advances, continuous assessment of valid and reliable methods for determining SB and physical activity will guide researchers in proper measurement. Collaborative efforts that include nursing, medicine, exercise physiologists, and others are needed to interpret SB measurement and to explore the implications of SB on healthy lifestyles.

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Figure 1. Conceptual model of sedentary behavior as adapted from the Theory of Planned Behavior

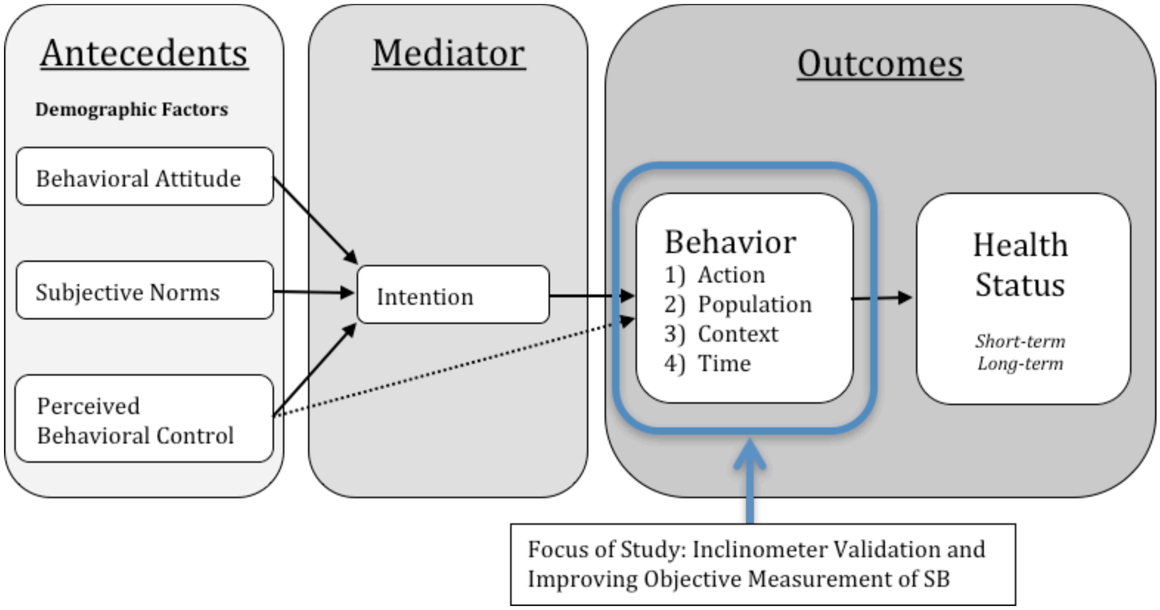

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Table 1. Demographic characteristics of the university males (n=12) and females (n=16)

Items	**Males, n (%)**	**Females, n (%)**
Age (years)		
18	2 (16.7)	6 (37.5)
19	4 (33.3)	7 (43.8)
20	6 (50.0)	3 (18.8)
Race		
White/Caucasian	9 (75.0)	12 (75.0)
Other/Mixed	3 (25.0)	4 (25.0)
Body Mass Index (kg/m^2)		
Overweight (≥25.0)	2 (16.7)	3 (18.8)
Not overweight (<25.0)	10 (83.3)	13 (81.2)
Waist Circumference (cm)		
Overweight (M ≥102, F ≥88)	1 (8.3)	5 (31.2)
Not overweight (M <102, F <88)	11 (91.7)	11 (68.8)

Table 2. Percent accuracy on each behavior by method with 95% confidence interval.

Method	Correct Code	Mean % coded correct	95% Conf. Int.	% coded sedentary	% coded active
Inclinometer					
Lying	Sedentary	80.8	66.1-95.5	80.8	19.2
Sit	Sedentary	70.1	54.5-85.7	70.1	29.9
Read	Sedentary	56.9	40.4-73.4	56.9	43.1
Game	Sedentary	44.9	27.1-62.7	44.9	55.1
Video	Sedentary	55.3	37.1-73.4	55.3	44.7
Talk	Sedentary	63.6	45.4-81.9	63.6	36.4
Stand	Sedentary	93.7	86.1-100	93.7	6.3
Bike	Active	73.0	60.0-86.0	27.0	73.0
Walk	Active	100.0	100-100	0.0	100
Axis100					
Lying	Sedentary	100	100-100	100	0.0
Sit	Sedentary	100	100-100	100	0.0
Read	Sedentary	100	100-100	100	0.0
Game	Sedentary	98.8	96.4-101.3	98.8	1.2
Video	Sedentary	100	100-100	100	0.0
Talk	Sedentary	98.8	96.4-101.3	98.8	1.2
Stand	Sedentary	100	100-100	100	0.0
Bike	Active	54.8	35.7-73.8	45.2	54.8
Walk	Active	100	100-100	0.0	100
Axis150					
Lying	Sedentary	100	100-100	100	0.0
Sit	Sedentary	100	100-100	100	0.0
Read	Sedentary	100	100-100	100	0.0
Game	Sedentary	100	100-100	100	0.0
Video	Sedentary	100	100-100	100	0.0
Talk	Sedentary	100	100-100	100	0.0
Stand	Sedentary	100	100-100	100	0.0
Bike	Active	48.8	30.0-67.6	51.2	48.8
Walk	Active	100	100-100	0.0	100
VM100					
Lying	Sedentary	100	100-100	100	0.0
Sit	Sedentary	95.2	90.6-99.8	95.2	4.8
Read	Sedentary	97.6	94.2-101.0	97.6	2.4
Game	Sedentary	94.0	89.0-99.1	94.0	6.0
Video	Sedentary	91.7	85.0-98.4	91.7	8.3
Talk	Sedentary	91.7	85.0-98.4	91.7	8.3
Stand	Sedentary	90.5	80.6-100.3	90.5	9.5
Bike	Active	100	100-100	0.0	100
Walk	Active	100	100-100	0.0	100
VM150					
Lying	Sedentary	100	100-100	100	0.0
Sit	Sedentary	96.4	92.4-100.5	96.4	3.6
Read	Sedentary	100	100-100	100	0.0
Game	Sedentary	96.4	92.4-100.5	96.4	3.6
Video	Sedentary	95.2	89.4-101.0	95.2	4.8
Talk	Sedentary	95.2	89.4-101.0	95.2	4.8
Stand	Sedentary	96.4	91.0-101.8	96.4	3.6
Bike	Active	100	100-100	0.0	100
Walk	Active	100	100-100	0.0	100

Table 3. Categorical and overall percent accuracy by method with 95% confidence interval

Method	Sedentary Accuracy	Active Accuracy	Overall Accuracy
	Percent (95% Confidence Interval)		
Inclinometer	66.5 (59.1-73.9)	86.5 (80.0-92.9)	70.9 (65.0-76.9)
Axis100	99.7 (99.0-100.4)	77.4 (67.9-86.9)	94.7 (92.4-97.0)
Axis150	100.0 (100.0-100.0)	74.4 (65.0-83.8)	94.3 (92.2-96.4)
VM100	94.4 (91.0-97.8)	100.0 (100.0-100.0)	95.6 (93.0-98.3)
VM150	97.1 (95.0-99.3)	100.0 (100.0-100.0)	97.8 (96.1-99.4)

Chapter 5: Manuscript 3 – Analysis of Sedentary Behavior of Older Adolescent University Students

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Analysis of Sedentary Behavior of Older Adolescent University Students

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Abstract

Objective: The purpose of this study was to examine relationships of an objective measure of sedentary behavior (SB), a physical activity measure, and self-reported sedentary habits, compared to body mass index (BMI) and waist circumference (WC) of older adolescent university students. **Participants**: Male (n=48) and female (n=46) students, ages 18 to 20 years, participated in this study from August to October 2013. **Methods**: Hierarchical multiple regression analyses examined predictor variables of SB, moderate to vigorous physical activity (MVPA), number of self-reported sedentary habits and body size as measured by BMI and WC. **Results**: Undergraduate students averaged 10 hours of SB and 68 minutes of MVPA daily. SB and MVPA correlated negatively with body size, and number of self-reported sedentary habits correlated positively. **Conclusions**: There is a need for future research on populations who already have high MVPA, but who also have high SB, in order to reduce health risk.

Keywords: sedentary behavior, physical activity, college, overweight, obesity

Analysis of Sedentary Behavior of Older Adolescent University Students

Numerous national and international organizations such as the American Academy of Pediatrics,[1] American Heart Association,[2] Centers for Disease Control and Prevention,[3] Institute of Medicine,[4] and World Health Organization[5] recognize the deleterious effects of sedentary behavior (SB) in youth, from childhood to young adults. According to the Sedentary Behavior Research Network[6], SB is any non-sleep behavior that uses minimal energy expenditure (≤1.5 metabolic equivalents [METs]) and is done in a seated or reclined posture—a definition that is supported in the literature.[7–10] Based on this definition, SB is its own unique behavior and is not necessarily a lack of or opposite to physical activity (PA).

The fundamental development of all youth includes the propensity to not be sedentary. For example, youth typically average 10-15 seconds on any one particular SB or physical activity.[11] Although attention span grows and ability to focus on tasks increases through the adolescent years, this generally highlights how the body is primed for movement rather than inactivity.

Although SB research has not quite risen to the level of prominence that has been focused on PA and obesity, an increasing number of studies in populations such as in older adolescents recognize the independent importance of SB on acute and chronic problems such as cardiovascular disease, metabolic syndrome, and colorectal cancer.[12–14] The global rise in acute and chronic morbidities is evidence that being sedentary for prolonged periods is unnatural and unhealthy. For example, adolescent Chinese youth have more than doubled the amount of time spent in SB over an 8-year span ending in 2004.[15] At least part of this is due to the relationship between SB and overweight and obesity.[16–18] With respect to weight-status, current research notes the prevalence of all youth who are overweight in the United States (U.S.) is 33.6% and obese is 18.4%.[19] Obesity has increased approximately 300% in roughly one generation.[19] Similar findings have been found in other populations.[20]

Obesity and SB are associated with numerous comorbidities, ranging the entire gamut of somatic and psychological disorders[21] such as one study finding that 70% obese adolescents had at least one risk factor for cardiovascular disease, and nearly 40% had two risk factors.[12] The cost of SB and obesity is not minimal, with a huge need to reverse the course. Efforts in reducing SB leading to a decrease in obesity rates by 5% would lower health care costs in the U.S. by $29.8 billion in 5 years, $158.1 billion in 10 years, and an impressive $611.7 billion in 20 years.[22] Sedentary behavior and weight disturbances are linked with early morbidity and death.[2,23,24] Some have even speculated that the current generation may have a shorter life expectancy than their parents.[2,24]

Using BMI and WC for measures of health

There are many ways to measure the impact of SB on health. Body mass index (BMI) and waist circumference (WC) are simple measures to assess ideal weight and predict health risks. Since body size is not easily or quickly manipulated, this presents an objective way to measure how behavior and activity over time have impacted adiposity and body shape. BMI and WC are also the two of the most common methods of measuring body size. A higher BMI in childhood and adolescence has been shown to correlate with an increased risk of cardiovascular diseases in adulthood.[25] For individuals ≥18 years-old, a BMI of ≥ 25 kg/m^2 (but < 30 kg/m^2) for overweight and ≥ 30 kg/m^2 for obesity are generally good cutoffs that demonstrate a significantly elevated risk for health problems, including cardiovascular diseases.[26] Waist circumference is another good indicator of adiposity and is positively correlated with morbidity.[27] Specifically, a of WC of ≥88cm in women and ≥102 cm in men is significantly related to increased health risks, particularly cardiovascular.[28] Waist circumference in particular appears to be a stronger predictor of health outcomes than BMI according to the National Health and Nutrition Examination Survey (NHANES) data.[29] Although the typical American cutoffs were used in this study, different BMI and WC cutoff values have been found in varying ages and ethnicities[30,31] such as a lower WC threshold in Asian adults[32,33] and adolescents.[34]

The older adolescent population

Older adolescents are of particular concern in this field. Between the ages of 18 and 20, changes from puberty are finished or nearly completed, having achieved, or close to, adult stature and at the same time this population typically has increased autonomy.[35,36] Older adolescents who are college students experience a great amount of independence. For many this is the first time living away from home. This population falls under Erikson's developmental stage of *identity vs. role confusion* where identifying personal values is a crucial part of this stage.[35] One manifestation of these values can be measured in terms of SB and PA and should better reflect the identity they seek for themselves without the constant influence of parents or guardians. Older adolescents in particular have the largest increase in SB and obesity, and the greatest decrease in moderate-to-vigorous PA (MVPA) over the last few decades compared to other groups.[36] Older adolescent college students experience over 30-40 hours/week of SB while most do not meet recommended MVPA guidelines, all while significantly increasing their weight.[36]

There is a general decline in motivation to increase activity and decrease SB as adolescents get older. Numerous studies have found that younger adolescents value activity and have a willingness to embrace a healthier lifestyle.[37–42] However, motivation for physical activity decreases with age at some time during the older adolescent years.[43–47]

Looking at university students specifically, overweight and obesity rates appear slightly lower than the national average. One study found the prevalence of overweight and obesity by BMI in college students to be 21.6% and 4.9%, respectively.[48] However, college students average participation in PA is less than 3 days per week, which decreases with age.[48]

Theoretical framework: the Theory of Planned Behavior

Many different theories and conceptual models are useful to explain and relate SB to health outcomes. Unlike other theories that are based on environments and relationships between people and populations, the Theory of Planned Behavior (TPB) is a framework that relates behavior choices and outcomes at the individual level.[49] Ultimately, individuals must be responsible for their own actions and health, thus the TPB is a suitable way to understand and analyze SB and PA choices in older adolescents who are experiencing an increased amount of individual freedom and choices while at college. Describing leisure-time choices in adolescents was one of the first uses of the TPB.[50] This theory has been used to explain SB and PA in adolescents and undergraduate students.[51–54] The application of TPB to this study is shown in Figure 1. In summary, the purpose of this study was to examine the effects of an objective measure of SB, a PA measure, and a participant-provided list of sedentary habits in older adolescent university students, on body size as measured by BMI and WC using the TPB as a guiding framework.

METHODS

Power Analysis

Power analysis was done using the computer program nQuery (Statistical Solutions, Ltd., Los Angeles, CA). Estimating the appropriate sample size was based on number of participants used in similar research[55,56] and following general consensus on principles of statistics which indicate multiple regression analyses should have 10-15 participants per independent variable.[57] Estimates using the program nQuery recommended a minimum of 59-65 subjects to achieve 80% power to determine meaningful associations between our factors of interest. In total, 101 participants were recruited for the study.

Participants and Procedures

After obtaining institutional review board approval from the university, recruitment was done by several means: university emails, fliers, electronic newsletters, and word-of-mouth. Inclusion criteria were English-speaking male and female university students, ages 18- to 20-years. Participants could not have any injury or condition such that their ability to walk and get around was different than normal. During recruitment, a screening process was done to verify eligibility and to attempt to keep the sample diverse. For example, there was a high rate of female responders interested in participating in the study, but study selection was done so as to keep gender percentages about equal. Participants met with the researcher for 15 minutes at the beginning of the study and fitted with the small ActiGraph GT3X+ accelerometer placed around the waist at the right hip with an elastic band and buckle. They then returned for 15 minutes again exactly one week later to return the device. On the initial visit, and after completing written informed consent, participants were assigned a code number and then completed a simple demographic form developed by the researcher. On the initial visit only, participant weight, height, and WC were taken in duplicate. Weight was assessed to the nearest 0.1 pounds using a digital scale (Seca Scale Robusta 813, Birmingham, UK). Height was recorded to the nearest 0.1 cm using a stadiometer (Shorr Height Measuring Board, Olney, MD). A measuring tape (Lifetime Measuring Tape, Prym-Dritz Corp, Spartanburg, SC) was placed directly onto the skin at the level of the iliac crest, just below the umbilicus, to the nearest 0.5 cm in determining waist circumference. Incentive for participation in the study included a $20 gift card for those with at least 10 hours of valid accelerometry data on at least 3 weekday days and at least 1 weekend day.

Measures

Demographics

The demographic questionnaire contained only 5 questions, eliciting gender, age, number of semesters in school, ethnicity, and listing extracurricular activities. The purpose of the final question was to compare results of the objective measurement of SB through accelerometry and the health measures of BMI and WC to the subjective responses on extracurricular activities. The list of extracurricular activities on the questionnaire were designated as SB or PA according to a compendium of behavior and activities as scored by METs according to the threshold of ≤1.5 METs for SB and all else as PA.[58]

Accelerometry

Accelerometers are an objective tool for collecting activity data. Accelerometers have been used to objectively measure activity since the 1990s and support for their validation is abundant.[59–63] The ActiGraph GT3X+ accelerometer is a small device weighing only 19 grams[64] and is well-tolerated by participants, including university students.[59] Participant completion and usable device data exceeds 90% in most studies for youth.[16,60,65–67] Missing data has been noted to range from 0% to 3%.[59] Accelerometry precision ranges 80-98% for SB in laboratory conditions[65,68] and in free-living conditions.[61,62] The device construct validity is high (r=0.39-0.90)[59] with SB measurement accuracy between 80-98% agreement with direct observation.[60,65] Additionally, the ActiGraph GT3X+ generally has a higher accuracy in comparison to other accelerometer devices.[59] Data was collected at 30 Hz and then aggregated during the post-collection processing stage to 1-minute intervals. Times of >60 minutes of accelerometer count values equal to 0 was considered time when the GT3X+ was not worn (non-wear time).[69] After removal of these data points, days with at least 10 hours of valid accelerometer data were retained for further processing.[70] The low-frequency extension feature was used with the intent that it would help capture sedentary-level movement. Count values obtained from the device were categorized by intensity level by applying the thresholds used for the NHANES accelerometer data with adjustment of the sedentary level to fit recent evidence specific for the device[71] (sedentary < 150 counts/min; light, 150-2019 counts/min; moderate, 2020-5998 counts/min; vigorous, >5999 counts/min).[69]

Data analysis

Statistical analyses were performed using SPSS 22.0 (IBM Corp., Chicago, IL). Hierarchical multiple regression was completed using demographic variables, the number of SBs listed on the questionnaire, and activity level as predictors of BMI and waist circumference. Ethnicity was vector coded with Caucasian as the comparison group for Asians and all other minorities. Statistical analyses used two-tailed testing of *p*-values with an alpha of 0.05.

RESULTS

Of the 101 participants that consented to do the study, 94 (93.1%) had enough valid data to be used for analysis. Of the seven participants that lacked sufficient data, four lacked at least one valid weekend day of 10 hours or more, two lacked both weekday and weekend days of valid data, and one got sick at the beginning of the study and could not complete the study. When computing the hierarchical multiple regression models, all statistical assumptions were met. Race was categorized into 3 groups: Caucasian, Asian, and other (African American, Hispanic, and mixed). This final group was formed because of overall low participant numbers in these groups. Caucasians were the referent group in the multiple regression analyses.

Basic demographical characteristics of the sample appear in Table 1. A breakdown of how many students were overweight by: a) BMI, b) WC, c) BMI or WC, and d) BMI and WC is shown in Table 2. The mean wear time per day was 868 (*SD=77*) minutes. Average time per day spent in SB was 599 (*SD=72*) minutes, light PA 201 (*SD=41*) minutes, and MVPA 68 (*SD=27*) minutes. Average daily percent of time spent in SB, light PA, and MVPA was 68.9 (*SD=5.0*) percent, 23.2 (*SD=4.4*) percent, and 7.9

(*SD=3.1*) percent, respectively. All of the sedentary and active extracurricular activities the undergraduates reported on the PIF appear in Table 3.

The overall model with all predictors was significant and explained 32.6% of the variance in BMI (see Table 4). In Block 1, gender, age, and Asian and other race comparisons to Caucasians explained 13.0% of the variance in BMI, which was significant. In Block 2, the addition of average daily percent of time spent in MVPA uniquely explained 0.8% of BMI after controlling for gender, age, and race. Overall, this block was significant. In Block 3 after controlling for all other predictors, average daily percent of time spent in SB and number of SBs listed on the questionnaire were added and uniquely explained 18.8% of the variance in BMI, which was significant.

When all predictors were included in the model for BMI, the race comparison of other to Caucasian, average daily percent of time spent in MVPA, average daily percent of time spent in SB, and number of SBs listed on the questionnaire were individually significant predictors, while gender, age, and the race comparison of Asian to Caucasian were non-significant. Of the significant predictors, being a non-Asian minority contributed most to the explanation of variance in BMI, followed by number of SBs listed on the questionnaire, then average daily percent of time spent in MVPA, and lastly average daily percent of time spent in sedentary behavior. Controlling for all other predictors, when participants were neither Asian nor Caucasian, BMI went up by 2.321 points. Controlling for all other predictors, as number of SBs listed on the questionnaire increases by 1, BMI goes up by 0.930 points. Controlling for all other predictors, as average daily percent of time spent in MVPA increases by 1 point, BMI goes down by 0.308 points. Controlling for all other predictors, as average daily percent of time spent in

SB increases by 1 point, BMI goes down by 0.289 points. Although not statistically significant, clinical significance was noted for both gender and age in the final model. After controlling for the other variables, being female equated to an increase in BMI by 0.927 points. Similarly, an increase in age by 1 year reflected an increase in BMI by 0.680 points. Example, when comparing demographic information only, being a non-Asian minority, 3rd year university female equates to a 3.928 point increase in BMI, compared to a Caucasian 1st year university male student.

Using WC as the dependent variable, the overall model with all predictors was significant and explained 17.5% of the variance (see Table 4). In Block 1, gender, age, and Asian and other race comparisons to Caucasians explained 8.5% of the variance in WC, which was not significant. In Block 2, the addition of average daily percent of time spent in MVPA did not uniquely explain any variance in WC after controlling for gender, age, and race. Overall, this block was non-significant. In Block 3 after controlling for all other predictors, average daily percent of time spent in SB and number of SBs listed on the questionnaire were added and uniquely explained 8.9% of the variance in WC, which was significant.

When all predictors were included in the model for WC, average daily percent of time spent in SB was the only individually statistically significant predictor, while all others were non-significant. After controlling for all other predictors, as average daily percent of time spent in SB increases by 1 point, WC goes down by 0.479 cm. Although not statistically significant, clinical significance was noted for gender, age, non-Caucasian non-Asian ethnicity, and number of SB items listed on the questionnaire. After controlling for the other variables the following demographics increased WC: female was an increase of 3.045 cm, each 1 year of age older was an increase by 1.143 cm, and non-Asian minorities compare to Caucasians was an increase of 2.894 cm. Similarly, an increase in the number of SBs reported on the questionnaire reflected an increase in WC by 1.620 cm. As an example, when comparing demographic information only, being a non-Asian minority, 3rd year university female equates to a 7.082 cm increase in WC, compared to a Caucasian 1st year university male student.

COMMENT

The relationship between SB, MVPA, and health is complicated and multi-faceted. Studying at the level of the individual and using the TPB as a framework is important in understanding the factors associated with sedentary choices and how they relate to health.[49,50] This study contributes another dimension of analysis of sedentary behavior in older adolescent university students to the overall body of research.

Perhaps the most interest finding of the sedentary analysis was the lack of evidence that higher amount of sedentary time correlated with higher BMI or waist circumference. In fact, the inverse relationship between body size and average daily percent of time spent in SB was the only common statistically significant factor in both the BMI and WC regression models. Several reasons may account for this seemingly paradoxical result. In some populations, research has indicated that individuals who are highly active and participate in sports also have more sedentary time.[72] Additionally, there is evidence to suggest that most individuals fall into one of only a few dominant behavior and activity level categories. For example, one study of pre-adolescents noted most participants fit into one of three groups: high SB with high PA, low SB with high PA, and moderate SB with low PA.[8] In another similar study that included both children and adults (including older adolescents), more than one third of the adolescent and adult participants were categorized with disproportionately highly SB and yet still met recommended daily PA guidelines.[9] These studies reinforce the concept that populations with high amounts of PA may also demonstrate excessive SB. Uncharacteristic of most study samples, the participants in this research averaged 68 minutes of MVPA every day. At the same time, they also averaged 10 hours of sedentary time per day. These results support the studies that suggest individuals with higher MVPA also have high amounts of time spent in sedentary behavior.

Clearly, other factors likely also play important roles in body size and health. Dietary choices cannot be ruled out as a factor influencing the results of this study. Evidence in adolescents indicates that excessive time spent in watching television and videos leads to an increase in poor dietary choices, while the opposite is true for adolescents who spend more time completing homework and reading since this is associated with more healthy eating behaviors.[73] Since the focus of this research was to analyze measures of SB and PA, nutrition was not a component in this study. However, because body size is a balance between energy in (diet) and energy out (behavior and activity level), nutrition always has some role in BMI and waist circumference.

Participants in this study were asked not to remove their device for any daytime napping that occurred during the data gathering process. Part of the reasoning behind this was to limit insufficient wear-time by the participants. However, the role of daytime sleeping in SB and its measurement has not been fully explored. Nighttime sleep has distinctive restorative benefits that improve health and is required to maintain optimal body functioning and metabolism.[74] The relationship between sleep, SB, and exercise is complicated, with evidence suggesting that the timing of each plays a role in health status.[75] Consistent, satisfactory sleep improves metabolic health and is important in hormonal regulation.[76] However, in adults, daytime napping is significantly related to decreased nighttime sleep, increased BMI and WC and higher overall cardiovascular risk.[77] In the pediatric population, including older adolescents, shorter nighttime sleeping in conjunction with SB is correlated with increased weight.[78]

Although daytime sleep seems to influence health status, research in older adolescents is minimal in terms of relationship of daytime sleep with SB and objective measurement. Lack of validated methods of objectively defining and measuring daytime sleeping in older adolescents is one reason for the dearth of information. Accelerometry provides a realistic way to measure SB objectively. This method can also be used to measure sleep, although results can be limited and should include other methods of measurement to improve accuracy.[79] The design and use of the accelerometers themselves differs in how they are utilized for measuring activity and sleep. Furthermore, not all accelerometers are validated for measuring sleep.[80] Some accelerometers are calibrated for activity, SB and sleep, but placement of the device on the body differs by which measurement is sought.[80]

As supported by the results of this study, the simple process of writing extracurricular activities helps identify those individuals who have an increased body size, and therefore at risk for negative health outcomes. Similar results have been found in other studies using diaries. For example, one study of university students found that individuals who had stronger sedentary habits reported being more sedentary via diaries compared to their peers.[81] In a study of Australian adults, self-report of television viewing was linked to undiagnosed glucose dysregulation and metabolic syndrome.[77] Therefore, despite the need to improve objective measures of SB, subjective methods including self-report of SB and PA, have a place for identifying relationships between behavior, activity level, body size, and health status.

Focusing solely on increasing PA alone is not adequate in attempting to improve the health of older adolescents. Research indicates that efforts to reduce SB may have a greater impact on increasing PA than targeting PA alone.[82,83] Maintaining healthy habits including reducing SB and improving PA is essential, even in the otherwise fit person. For example, one recent study found that even persons who are normally physically active begin to have impaired glucose management within a matter of days of adopting a sedentary lifestyle.[84]

Limitations

Although this study supports and adds to the current body of SB literature, there were some limitations of this study. The convenience sampling and self-selection process of the participants inherently brings issues of sampling bias. Students who are sedentary might not be interested in participation in a "physical activity study," as it was advertised. Also, during the recruitment process, females, first-year university students, and Asians were strong referrers to friends and colleagues. Recruitment of the other groups had to be escalated to try to boost participant numbers and diversity. Since social networking and friendship groups play an important role in an individual's choice to be active or sedentary, the referrals from the participants themselves may have influenced the sample in the direction of those who were already highly active and highly sedentary while maintaining a lower BMI and waist circumference.[85,86] Also, nutrition was not included as part of this study, which constitutes the “energy in” portion of the energy balance equation. Finally, study participants were not asked if they were currently trying to lose weight, which may have affected their choices regarding both SB and MVPA.

Conclusion

The results of this study highlight the importance of knowing the target population. Demographic characteristics of the sample play an important role in body size at baseline and are potential factors for tailoring individual interventions or targeting population in the future. Populations with high amounts of daily MVPA may also have high amounts of sedentary behavior. Average daily percent of time spent in SB and MVPA, as well as number of self-reported extracurricular sedentary habits, play a role in describing the body size of older adolescent university students. In looking toward future research, understanding and seeking interventions for older adolescents may afford the opportunity for achieving the greatest potential benefit by providing a lifetime of positive behaviors that maximizes healthy outcomes.

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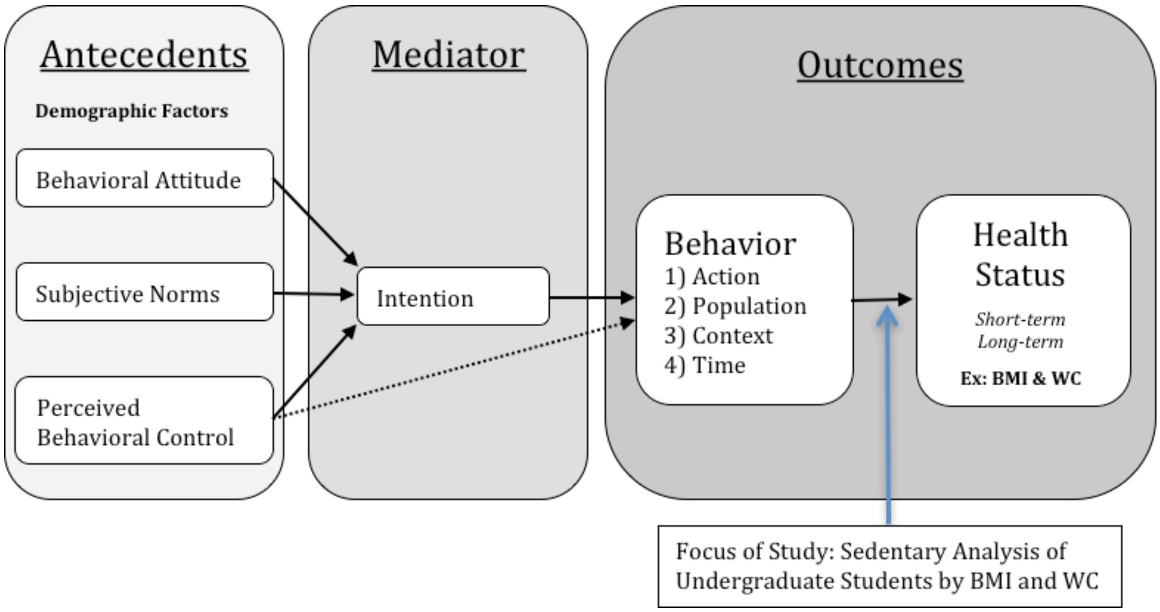
Figure 1. Conceptual Model of Sedentary Behavior as Adapted from the Theory of Planned Behavior



Adapted from Theory of Planned Behavior, Ajzen, I. (1991). The theory of planned behavior. Organizational behavior and human decision processes, 50(2), 179–211. doi:10.1016/0749-5978(91)90020-T

Table 1. Demographic Characteristics, Independent, and Dependent Variables

Characteristic	*n*	%	*M*	*SD*	*Min-Max*
Gender					
Male	48	51.1			
Female	46	48.9			
Age (years)					
18	30	31.9			
19	30	31.9			
20	34	36.2			
Race					
African American/Black	3	3.2			
Asian	37	39.4			
Caucasian/White	40	42.6			
Hispanic	6	6.4			
Other/Mixed	7	7.4			
No response	1	1.1			
College Year					
1st Year	29	30.1			
2nd Year	31	33.0			
3rd Year	32	34.0			
4th Year	2	2.1			
Body Mass Index (kg/m^2)					
Male			23.3	2.7	17.9-28.4
Female			24.4	4.2	16.3-40.9
Waist Circumference (cm)					
Male			85.3	7.4	71.5-105.8
Female			88.7	9.6	69.8-116.5
Sedentary Behavior (min)			599	72	448 – 764
Moderate-to-Vigorous Physical Activity			68	27	20.9 – 173.8

Table 2. Percentage of Sample Overweight by Categories

	n	%
BMI		
Male	13	13.8
Female	15	16.0
WC		
Male	16	17.0
Female	4	4.3
Either BMI or WC		
Male	18	19.1
Female	15	16.0
Both BMI and WC		
Male	11	11.7
Female	4	4.3

Note. BMI= Body Mass Index (kg/m^2), WC= Waist Circumference (cm)

Table 3. Student Reported Extracurricular Activities.

Sedentary (*N*)	Active (*N*)
Reading (51)	Running (35)
Video games (25)	Weightlifting (27)
Television (20)	Basketball (14)
Studying (19)	Biking (10)
Computers (11)	Student clubs (9)
Napping (5)	Tennis (9)
Movies (4)	Walking (9)
Writing (4)	Cooking (8)
Drawing (3)	Soccer (8)
Art (2)	Volunteering (8)
Card games (2)	Rowing (7)
Eating (2)	Swimming (7)
Meetings (2)	Volleyball (7)
Music (2)	Dancing (6)
Time with friends (2)	Football (5)
Tutoring (2)	Gym (5)
Attend sports games (1)	Jogging (5)
Chess (1)	Baking (4)
Crafts (1)	Hiking (4)
Food enthusiast (1)	Frisbee (3)
Homework (1)	Working out (3)
Lifeguarding (1)	Boxing (2)
Phone caller for work (1)	Camping (2)
Research (1)	Church activities (2)
Sedentary pursuits (1)	Coaching (2)
Sitting (1)	Guitar (2)
Sleeping (1)	Piano (2)
	Racquetball (2)
	Sand volleyball (2)
	Softball (2)
	Sports (2)
	Taekwondo (2)
	Violin (2)
	Wushu (2)
	Yoga (2)
	Babysitting (1)
	Baton twirling (1)
	Cardio workout (1)
	Caregiver (1)
	Catering (1)
	Cello (1)
	Circuit training (1)
	Classroom assistant (1)

	Cross-fit training (1) Debating (1) Exercising (1) Field hockey (1) Flute (1) Horseback riding (1) Ice hockey (1) Kickboxing (1) Lacrosse (1) Marching band (1) Nannying (1) NROTC (1) Photography (1) Pilates (1) Ping pong (1) Playing with dogs (1) Quidditch (1) RA (1) Rock climbing (1) Sailing (1) SCUBA diving (1) Self-defense (1) Shopping (1) Stairs (1) Student government (1) Zumba (1)

Table 4. Hierarchical Multiple Regression of Factors Associated with BMI and WC

BMI as the Dependent Variable						
	R^2	R^2 *change*	*F change*	*p*	β	*p*
Block 1	.130	.130	3.333	.014		
Gender: Female vs. Male					.828	.252
Age					.493	.262
Race: Asian vs. Caucasian					.359	.648
Race: Other vs. Caucasian					3.027	.003
Block 2	.138	.008	.773	.021		
Gender: Female vs. Male					.730	.319
Age					.367	.428
Race: Asian vs. Caucasian					.250	.753
Race: Other vs. Caucasian					2.834	.007
Ave. daily % MVPA					–.111	.382
Block 3	.326	.188	11.995	.000		
Gender: Female vs. Male					.927	.159
Age					.680	.109
Race: Asian vs. Caucasian					.160	.822
Race: Other vs. Caucasian					2.321	.013
Average daily % MVPA					–.308	.017
Average daily % SB					–.289	.000
Number of SBs listed					.930	.006

WC as the Dependent Variable						
	R^2	R^2 *change*	*F change*	*p*	β	*p*
Block 1	.085	.085	2.068	.092		
Gender: Female vs. Male					2.762	.130
Age					.675	.541
Race: Asian vs. Caucasian					–1.544	.435
Race: Other vs. Caucasian					3.862	.127
Block 2	.085	.000	.035	.157		
Gender: Female vs. Male					2.709	.145
Age					.607	.603
Race: Asian vs. Caucasian					–1.603	.426
Race: Other vs. Caucasian					3.758	.149
Ave. daily % MVPA					–.060	.851
Block 3	.175	.089	4.644	.018		
Gender: Female vs. Male					3.045	.089
Age					1.143	.318
Race: Asian vs. Caucasian					–1.758	.365
Race: Other vs. Caucasian					2.894	.250
Average daily % MVPA					–.386	.265
Average daily % SB					–.479	.018
Number of SBs listed					1.620	.074

Note. MVPA=moderate-to-vigorous physical activity. SB=sedentary behavior.

Chapter 6: Conclusion

This dissertation focused on novel methods of objectively measuring sedentary behavior (SB) and an analysis of SB of older adolescent university students. Novel objective methods included validation of an inclinometer as well as analyzing the accuracy of single- versus multi-axis measurement with two different sedentary thresholds. The analysis of SB successfully evaluated patterns and amount of SB with body mass index (BMI) and waist circumference in using week-long accelerometry data from the university student population.

Results stemming from the first specific aim—testing novel objective methods of measuring SB—were encouraging in some ways. In general, the ActiGraph GT3X+ device performed well in measuring SB and physical activity in laboratory-controlled situations that simulated every day behaviors of older adolescents. Overall, the inclinometer feature was not so promising, with a sedentary accuracy of 66.5% and an overall accuracy of 70.9%. The ability to calibrate and adjust the angles on the device that code for lying and sitting positions would likely improve the accuracy of this feature in determining SB in older adolescents. The mathematical method of combining the X-, Y-, and Z-axes to make a vector, and increasing the threshold to 150 counts per minute, was the most accurate of all methods, with an impressive overall accuracy of 97.8%. Although calculating vectors to determine body movement is not commonplace in this field at this time, this novel method may produce more accurate detection of body movement, or lack thereof, in older adolescents and other populations as well.

The analysis of SB of the undergraduate students and attempting to develop the Sedentary Outcome Score (SOS) was the second aim of the dissertation. Although unexpected, the results complement findings and augment the understanding of the older adolescent university student population. Firstly, the older adolescent student population at this particular university did not meet the expected findings or compare with national averages. In general, these students were both highly active and highly sedentary. Results in similar populations corroborate these findings (Jago, Fox, Page, Brockman, & Thompson, 2010; Spittaels et al., 2012). Secondly, the older adolescents identified extracurricular activities, which were coded as sedentary or active, and the number of SBs listed were used as predictors in the BMI and waist circumference regression models. The outcome of these analyses showed a positive correlation between number of SBs and body size as measured by BMI or waist circumference. Therefore, the more sedentary choices that older adolescents consider part of their regular extracurricular routine, the higher the body size. This surprising finding would indicate that identifying older adolescents at-risk for disproportionately high SB and obesity may be as simple as asking them to write down their extracurricular activities. Because of these unexpected, paradoxical findings, the investigator was not able to develop the innovative SOS algorithm. The associations found between SB, physical activity, and body size, in the sample of older adolescent college students, require further exploration.

The connections between body size, health, SB, and physical activity needs continual analysis and examination. Research findings support SB as an independent factor on weight and health status in older adolescents and adults (Healy et al., 2008; Jakes et al., 2003; Katzmarzyk, Church, Craig, & Bouchard, 2009) and in children (Ekelund et al., 2006; Saunders et al., 2013). Even with this evidence, the role of SB on health is not clear. Some research has indicated that, when adjusting for total amount of physical activity, there is a minimal association between SB and cardiac biomarkers using recent National Health and Nutrition Examination Survey data (Maher, Olds, Mire, & Katzmarzyk, 2014). Similar research in 12 year-old children also did not see SB associated with obesity once the statistical models accounted for moderate-to-vigorous physical activity (Mitchell et al., 2009). Clearly, the interplay between SB, physical activity, and health is complicated and needs additional investigation.

Results from this dissertation have implications for nursing education, practice, and research. With obesity officially being named a disease in 2013 (American Medical Association, 2013), nurses can no longer ignore this topic in educating student nurses, health care colleagues, and patients. The role of SB in excessive body size should be a part of this education, as well as its influence in other disorders such as metabolic syndrome and cardiovascular disease (Healy et al., 2008). As described in Chapter 4: Manuscript 2 – Inclinometer Validation and Sedentary Threshold Evaluation in Older Adolescent University Students, lack of movement along the y-axis, or up and down motion, seems to be particularly helpful in defining what is sedentary. Therefore, education about SB and reducing its impact should also include the importance of breaking up SB, such as physically standing up to reduce sitting and lying time. Although forward-and-back and side-to-side movement while seated may add some amount of activity, the results from the dissertation research on objectively measuring SB would indicate that lack of upward body motion (i.e. through standing) is important in defining and measuring behaviors that are sedentary.

Similar to education, this research should influence nursing practice. For example, just as early ambulation for post-operative patients is standard nursing practice for reducing morbidities and improving outcomes, nursing practice should integrate ambulation therapies for all patients. This would reinforce education on reducing SB time and the need to increase physical activity. Along these same lines, the common hospital bed may in fact be detrimental to healing for some patients as it fosters a sedentary approach to recovery. This is one area where additional nursing research could have a great contribution to the science.

Additional nursing research is needed to expand the breadth and depth of SB research. Although the dissertation did not utilize every aspect of the Theory of Planned Behavior for the research—instead focusing solely on the outcome variables of BMI and waist circumference—the theory provides the foundation for future studies by indicating the constructs and relationships that should be addressed in future work. Determining valid and reliable objective measurements of SB ensures that future studies using interventions will be able to detect changes and the direct effects of the intervention more accurately. Objective measures of SB should be validated in additional populations. Novel methods of measuring SB should also be tested when they are developed to ascertain if they capture additional insight either independently or in tandem with existing methods.

There are several immediate next research steps stemming from this dissertation. This includes additional research to improve objective assessment of sedentary time as well as enhancing how SB is analyzed statistically. Using an inclinometer to objectively measure SB could likely be made better through adjusting the angle definitions at which the device differentiates lying, sitting, and standing positions. Changing the placement of the device may also improve measurement, such as attaching the device to the thigh or upper leg instead of the waist. Using the existing dissertation dataset to investigate methods of combining inclinometry and accelerometry to detect sedentary and non-sedentary time should be fully explored.

With respect to the next steps for improving analyses of SB, the dose-response relationship between SB and body size as well as cardiovascular wellness needs further development through the Sedentary Outcome Score. Daily episodes of physical activity and SB, in addition to total daily physical activity and SB, are correlated with weight status and cardiovascular health in adults (Healy et al., 2008). This association has yet to be adequately explored in youth including older adolescents. Using national accelerometry data, such as the National Health and Nutrition Examination Survey, would allow for an adequate sample size and diversity for development of the Sedentary Outcome Score. Furthermore, interventions focusing on just physical activity may be missing the complete picture by not addressing sedentary behavior. For example, some research indicates that efforts to reduce SB may have a greater impact on increasing physical activity than targeting physical activity alone (Epstein et al., 2006; Robinson, 1999).

Development of the SOS is key to guiding intervention studies for future research. One possible interventional study would be the use of non-stationary seating for children at schools, such as exercise balls or stools with convex bottoms such as the Hokki (VS America, Inc., Charlotte, NC). Since sitting in a classroom constitutes the majority of a student's day, targeting this time has great potential. Treatment of obesity using the comprehensive guidelines from the American Academy of Pediatrics also needs to be tested and validated on a large scale (Barlow & the Expert Committee, 2007). Another future intervention would be to receive a text message (or similar prompt) when an accelerometer (such as the ones already encased in most smartphones) detects a prolonged period of sedentary time, as calculated by the SOS algorithm. This could be individualized by using patient-specific demographics and could also consider the patient's weight trends. For example, if the patient's weight was steadily on the rise, the SOS might compensate for this by recommending more frequent breaks in SB time. Finally, the built environment has been shown to contribute to childhood obesity (Rahman et al., 2011). On a grander scale, collaborative interventional research that included urban developers and architects may find home, school, and city designs that reduce SB, promote physical activity, and ultimately decrease obesity, such as the new Buckingham County Primary and Elementary Schools in southern Virginia (VMDO Architects, 2013). Any of these studies could be started within the five to seven year time frame given the right collaborations, support, and funding.

Overall, this dissertation adds to the body of knowledge on objectively measuring SB and the sedentary patterns of older adolescent university students with its relationship to body size. Nurses of all specialties, including nurse scientists, should understand the definition of SB, how it is measured, and its relationship to body size, which is an indicator of health including cardiovascular wellness (Han, van Leer, Seidell, & Lean, 1995; NHLBI Obesity Education Initiative Expert Panel on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults, 1998). This knowledge can influence patient health outcomes, as well as personal choices, in making smarter decisions about how daily SB routines relate to long-term health.

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